Studies on Tree-Crop Interaction in <u>Albizia</u> <u>procera</u> Based Agroforestry System in Relation to Soil Moisture, Light and Nutrients

THESIS

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FOR THE DEGREE OF

Doctor of Philosophy
(Agronomy)
By

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UNDER THE SUPERVISION & GUIDANCE OF

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NRCAF

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CERTIFICATE

This is to certify that the work embodied in this thesis entitled **"Studies on tree-crop interaction in *Albizia procera* based agroforestry system in relation to soil moisture, light and nutrients"**, submitted by **Sh. Mukesh Kumar Bhargava**, for the award of Degree of **Doctor of Philosophy** to the Bundelkhand University, Jhansi, has been carried out under my supervision and guidance and no part of the work has been submitted elsewhere for the award of any other Degree.

This is also certified that **Sh. Mukesh Kumar Bhargava** has put in the attendance required under the statutes of the university during the course of the present investigation.

Dated: 21.10.03

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DECLARATION

I hereby state that the present work entitled **"Studies on tree-crop interaction in *Albizia procera* based agroforestry system in relation to soil moisture, light and nutrients"** has been carried out by me under the supervision and guidance of **Dr. Ram Newaj, Senior Scientist (Agronomy), National Research Centre for Agroforestry, Jhansi** and to the best of my knowledge, a similar work has not been carried out any where so far.

Dated: 21.10.2003

(Mukesh Kumar Bhargava)

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Introduction

CHAPTER I

INTRODUCTION

In agroforestry, tree and agricultural crops are combined together and they compete with each other for growth resources such as light, water and nutrients. The resources sharing by the components may result in complementary or competitive effects depending upon the nature of the species involved in the system, the manner in which they are grown and the climatic factors. Harper (1977) most thoroughly examined the importance of understanding the mechanism of plant interaction. While describing the nature of interactions, he focuses that plant may influence its neighboring species, not only adding or removing of some factor, but by affecting conditions such as temperature, light or wind movement and by altering the balance between beneficial and harmful insect.

The nature and quantum of these effects depends upon (i) age and size of the trees (ii) nature of the tree species (iii) nature of the agricultural crops (iv) availability of water, nutrients and light etc. In an intercropping system involving a legume and non-legume, part of the nitrogen fixed in the root nodule of the legume may become available to the non-legume component (Soundararajan and Palaniappan, 1979; Palaniappan *et al.*, 1976). The complementarity in resource capture under mixed cropping / intercropping system may be spatial or temporal. In temporal complementarity, the leaf canopies of component crops may occupy different vertical layers with taller component tolerant of strong light and high evaporative demand and shorter component favoring shade and high relative humidity. Multistoried cropping in coconut and planting shade trees in cocoa and tea plantation uses this principle. In similar manner under agroforestry system, exploitation of different layers of soil by the root systems of trees and crops may lead better utilization of resources with much less competition. In temporal complementarity, the yield advantages provided by the mixture cannot always are explained by more effective use of growth resources at specific times. Indeed, there are substantial opportunities for temporal complementarity if species make their major demands on available resources at different times, thereby reducing the possibility of competition. For example, the usually advantageous intercropping of the slow-growing pigeonpea with fast-growing cereals such as maize or sorghum produces only limited increase in total light or water use

(Natarajan and Willey, 1980) but nevertheless provides intercrop advantages of 40-70%. Main effects of tree-crop interactions are complementary effect for example, increase productivity, Improve soil fertility (organic matter addition), nutrient cycling, microclimatic improvement and sustainability and competitive effects such as above and below ground competition (yield reduction of crop components in various system due to tree component).

The overall (biomass) productivity of an agroforestry system is generally greater than that of an annual system although not necessarily greater than that of a forestry or grassland system. The basis for the potentially higher productivity could be due to the capture of more growth resources e.g. light or water or due to improved soil fertility. Competition, which is a negative effect in this context, is usually a significant factor in simultaneous agroforestry system, even when there is evidence of increased combined productivity by both components (Ralhan *et al.*, 1992; Sharma and Singh, 1992; Jagdish Chander, 1998).

In an agroforestry system, biomass production from trees adequately compensated the crop reduction due to competition with tree. Land equivalent ratio of agroforestry land use was comparable or even better than monocropping systems indicating suitability of this system (Pratap Narain *et al.*, 1998). Agroforestry gives more income to the farmer per unit area of land than pure agriculture or forestry. Several studies in different parts of the country suggested that agroforestry is more profitable to farmers than agriculture or forestry for a particular area of land (Singhal and Panwar, 1992; Mathur and Sharma, 1983; Mathur *et al.*, 1984; Jagadish Chander, 1998; Ralhan *et al.*, 1992, Toky, 1997).

Agroforestry plays as important role in resource conservation especially for soil. The primary objective of soil conservation is to improve / maintain soil fertility. To achieve this, control of erosion, maintenance of organic matter, maintenance of physical properties, organic matter addition, maintenance of nutrient is necessary. In this way agroforestry system constitute sustainable land use and help to improve soils in a number of ways. The utility of agroforestry practices and their symbiotic effects on better growth and yield of the crops is widely recognized. Agroforestry as subject of scientific investigation has assumed wider recognition in view of the need to maximise production on the basis of sustainable land management (Singh *et al.*, 1998). Some of these

beneficial affects are apparent in experiments carried out in different parts of the country. (Pradhan, 1973; Shankarnarayan, 1984).

In agroforestry system, nutrient cycling is one of the most important hypotheses. It is based on the capacity of tree root systems to trap nutrients in the soil solution that would otherwise be lost by leaching and to recycle them through litter to the soil surface. There are implications for systems with high or low inputs. For low-input systems, the hypothesis states that nutrient cycling can become highly efficient, so that following will only be necessary after long period. Alternatively, under conditions of weak leaching, continuous cultivation might be possible, with nutrient removal in crop harvest compensated by natural inputs. Under high-input systems, the hypothesis states that the ratio of nutrient recycling to nutrient losses will be greater for agroforestry than for agricultural systems, with consequent economic benefit through more efficient fertilizer use.

A scientific framework for a quantitative analysis of tree-crop interactions is needed for several reasons. First, it should provide a reliable method to determine which benefits are likely to be realized for a given agroforestry technology in a defined situation. Second, it should enable researchers to evaluate the relative importance of each interaction in order to guide to them more precisely in the choice of research priorities. This is no trivial matter because agroforestry research requires a long term commitment in research resources and it is not easy to separate the complex interacting factors involved in the system (Anderson and Sinclair, 1993). Third, the advantages of agroforestry cannot be quantified simply in term of productivity alone, because some of the benefits are due to environmental improvements, e.g. resulting from erosion control and increased organic matter content, and these cannot be measured in only a few seasons. Finally, a quantitative approach is an important step in the quest for a fuller understanding of the complex mechanisms of tree-crop interactions, which should then offer the scientific basis for designing yet more productive and sustainable agroforestry systems before considering methods to quantify the overall effect of tree-crop interaction, which should then offer the suitable basis for designing yet more productive and sustainable agroforestry system.

In much of the on-going studies, there is very little information available on quantification of below ground resources (soil moisture and nutrients) use by the

component species. The study will provide information on above (light) and below ground competitive effects in *Albizia procera* / blackgram-mustard interface and will also demonstrate the various management practices (pruning, soil barrier and irrigation) to minimize competition and maximize complementary effects between the tree and crop component. The objectives of this study are given below.

1. To quantify the competitive effects between components of a tree-crop system for light, moisture and nutrients.

2. To examine the effect of pruning, soil barrier and / or management practices to minimize competition and maximize the complementary effect between tree and crop.

Review of Literature

CHAPTER II

REVIEW OF LITERATURE

A comprehensive review on tree-crop interactions, which were available in various National and International Journals/books/reports has been given in this chapter to know the views of scientists on tree-crop interaction and verify the results achieved in present study.

2.1 Effect of trees on crops and vice-versa

2.1.1 Effect of crop on tree growth

In tree-crop system, cultivation practices like preparation of field, fertilizer application, inter-culture, weeding, irrigation do affect the survival and growth of trees. Although during planting stage when trees are very small, at that time inter-crops having higher height than trees. At this stage, sometime crops may affect the availability of light and moisture for the trees. However after one year or two years when tree height increased then trees do compete with inter-crops for growth resources.

In an agri-silvicultural system at NRCAF, Jhansi, arable crops were raised in association with multipurpose trees during 1988 and 1989. Tree growth (height and collar diameter) was distinctly better under tree-crop system as compared to sole tree (control). It indicated complimentary interaction between tree and crop (Roy and Gill, 1991). In another study, Couto and Gomes (1995) found that tree growth and survival are unaffected when *Phaseolus vulgaris* intercropped with *Eucalyptus grandis* in agroforestry system and no disease or pests were detected in either the forest or agricultural species. Batra and Kumar (1994) studied on biomass production and nitrogen accumulation by three tree species (*Acacia nilotica, Dalbergia sissoo, Casuarina equisetifolia)* and rhodes grass (*Chloris guayana*) and their effect on each others in alkali soil during August, 1989 under agroforestry system. The height and girth of trees were not affected significantly in the presence of grass.

The tree growth, survival and crop yield under agrisilvicultural practices were analyzed over a seven-year period in a split plot experiment on acid alfisol under rainfed conditions at ICAR Research Farm, Barapani. Three indigenous species including a fruit plant and one introduced tree species formed the main plot treatments and three crop sequences were the sub-plot. The tree species were mandarin (*Citrus reticulata*), alder (*Alnus nepalensis*), cherry (*Prunus cerasoides*) and albizia (*Paraserianthes falcataria*). A positive effect of intercropping on height and diameter growth, crown width and timber volume was observed in alder, albizia and cherry but no appreciable differences for these parameters were observed in mandarin between the two situations. Alder and albizia attained maximum growth and mandarin recorded woody biomass followed by cherry and the minimum growth. The better growth and timber volume in the "tree+crop" situation was mainly due to the application of fertilizers and weeding (Dhyani and Tripathi, 1999). A silvipastoral studies were undertaken at the Regional Research Station of CAZRI at Pali (Rajasthan) in 1970, with four tree species (*Acacia tortilis, Azadirachta indica, Albizia lebbeck* and *Holoptelea integrifolia*) and in inter-spaces of these trees four different grasses (*Cenchrus ciliaris, C. setigerus, Dichanthium annulatum* and *Panicum antidotale*) were introduced. Trees without grasses were used as a control. The results revealed that no significant differences in grass production under trees and intercropping with grasses had no effect on tree growth (Muthana and Shakarnarayan, 1978). In this contrast, another study showed that the growth of *Acacia nilotica* was affected adversely by intercrop (grasses). In this study, *A. nilotica* seedlings were planted at a spacing of 8 m x 5 m in 1990 and the grasses like *Eulaliopsis binata*, *Vetiver zizanioides* and *Saccharum munja* were introduced as intercrop. Natural grass was kept as intercrop with *Acacia nilotica* and one of the plot was kept as control, where no grass was allowed to come up. Mean survival after 65 moths of planting of the species was 86 per cent under control and 75, 84, 55 and 64 per cent with intercrops as natural grasses, *E. binata*, *S. munja* and *V. zizanioides*, respectively. The highest height and dbh of *A. nilotica* was observed under control (no grass) as compared to *A. nilotica* grown with different grasses (Samra and Singh, 1998).

2.1.2 Effect of trees on growth and yield of associated crops

An important concern in agroforestry is the effect of one species, usually the tree component, on the intercrop component. In general, the tree species in association with crops in agroforestry compete strongly with crops for light, nutrients and moisture which has an adverse effect on the intercrop yield with increasing the growth of the trees (Ram Newaj *et al.*, 2001). Tree crop interaction effect can be quantified through the measuring of the yield at the tree/crop interface where tree and crop interact/compete for growth resources. Research results on tree-crop interface under various systems of agroforestry indicates that under agrisilviculture, the yield of wheat crop reduced up to 71 per cent in 5 m x 5 m spacing and 24 per cent in 10 m x 10 m spacing due to *Dalbergia sissoo* in age of two years (Nandal *et al.*, 1999). Similar result was also found in case of *Ceiba pentandra* with wheat crop, under this system the growth and yield attributing character was affected by the tree, if these characters were compared with sole crop (Puri *et al.*, 2001).

In an agrisilviculture study, twelve MPTS were grown at three spacing (2 m x 4 m, 2 m x 6 m and 2 m x 10 m)) and two crop sequences (sorghun-wheat and pigeonpea-wheat) were included in the system. The results showed that the minimum yield of crops were observed in first row and it was increased with increasing distances from the tree base (Gill, 2001). The productivity of the crops/cropping sequences increased with increasing tree spacing in *Dalbergia sissoo* based agroforestry system (Nandal and Singh, 2001). In other ways the yield of the crops increased with increasing distances from the tree trunk. In an investigation the productivity of jowar-toria crop sequence was tested with three plantations i.e. *Eucalyptus* hybrid, *Bombax ceiba* and mixed plantations (control) of *Cassia fistula, Bombax ceiba, Acacia catechu, Lannea coromandelica* and *Dalbergia sissoo.* It was observed that about 14.89, 12.79 and 12.14 t ha^{-1} green fodder yield of jowar could be obtained with *Bombax ceiba, Eucalyptus* hybrid and mixed plantations, respectively. The trend was same with toria and 3.68, 2.78 and 2.38 q ha^{-1} seed yield were recorded under *Bombax ceiba, Eucalyptus* hybrid and mixed plantations, respectively (Saroj *et al.*, 1999).

Dagar and Singh (2001) had observed a reduction in yield of all the crops, planted in inter-spaces of six-year-old plantation of *Casuarina equisetifolia* at 6 m x 6 m spacing under semi-arid region. Similarly in an another study, the TCI effect was observed in case *Melia azedarach* with sesbania, mustard, wheat and barley crops. The canopy of the trees adversely affected the intercrops. The yield of sesbania green manure was reduced upto 30 q ha^{-1} in presence of trees. The reduction in grain yield of mustard, wheat and barley was 48, 59 and 62 per cent respectively as compared to control (Goyal *et al.*, 2001). The effect of *Prosopis cineraria* tree on the yield of mustard crop was studied at various distances in irrigated and rainfed fields which reveals that the production is lowest within the first meter radius around the tree in all cases and this effect is more pronounced around tree and beyond 7 m under rainfed and up to 3 m in irrigated conditions (Yadav and Blyth, 1996). The influence of single row bund plantation of *Acacia nilotica* on the growth and yield of associated (wheat) crop under irrigated condition in Haryana indicated that the tree lines does affect all the growth and yield parameters in the vicinity of tree up to 4 m distance from tree lines, which establishes that, away from tree lines, the growth and yield of wheat crop also improved (Sharma, 1992). Similarly under agrisilvicultural system, the effect of *Populus deltoides* on wheat yield was observed under five age classes (one year, two year, three year, four year and six year old plantations). A substantial reduction was observed in wheat yield (23.3 %) under three year old poplar plantation (Ralhan *et al.*, 1992). Similar result was also found in case of 12 MPTS and three spacing (2 m x 4 m, 2 m x 6 m and 2 m x 10 m) with four crop rotation (Solanki and Ram Newaj, 1996). Under tree/crop interface in association with subabul, wheat and chickpea recorded a relative grain yield of 74.7 and 55.2 per cent, respectively. (Gill, 1999) examined the effect of *Leucaena leucocephala* on the thirteen wheat varieties under semi-arid conditions of the Central India. Wheat variety UP 2003 and UP 115 only gave higher grain and straw yield under agroforestry as compared to monoculture. In a farm field research study, wheat yield in the plots, oriented 2.5 m east, west and north from the canopy of a north-south row of 11-year-old Paulownia trees. Wheat yield was higher on the east orientation as compared with the west and north (Charles *et al.*, 1996).

The effect of mulberry (*Morus alba*), poplar (*Populus deltoides*), safed siris (*Albizia procera*) and subabul (*Leucaena leucocephala*) on the yield of rainfed wheat was studied at Dhaulakuan District Sirmour in Himachal Pradesh. Tree were planted in August, 1987 in 3 blocks in randomized block design with 2.5 m between trees and 25 m between rows (in N-S orientation), with trees of each species planted in group of 8. Wheat (var. Sonalika) was planted in Oct. 1992. In the case of safed siris, subabul and no tree (control), planting of trees at 10 m and 8 m distances gave higher wheat yield, whereas 6 m, 4 m and 2 m distances showed low yield (Chauhan *et al.*, 1995). The studies of tree- crop interaction have shown that the yield of un-irrigated wheat (grown in Rabi) and paddy (grown in Kharif) crops decreased consistently and progressively when *Grewia optiva, Morus alba and Eucalyptus* hybrid were grown along with them at 4 m x 5 m spacing. Over a period of 13 years there was an average loss of 29, 29 and 28 per cent in yield of wheat when grown in association with Grewia *optiva, Morus alba* and *Eucalyptus* hybrid, respectively (Khybri *et al.*, 1992). The results of four years (1984 to 1987) of the tree-crop interface (TCI) in the hedgerow intercropping did not show any effect of row orientation, and similarly, no effect was seen on crop rows due to their location on the windward or leeward side of hedge. The TCI effect was positive on the first crop row in the first year because *Leucaena* grew slowly, but depressed the yield of the first 4-6 rows (1.8 m to 2.7 m from hedge row) in subsequent years. The negative effect of *Leucaena* was noted more on sunflower in a relative dry year than on sorghum in other years (Rao *et al.*, 1991).

An investigation was made in *Prosopis cineria* based agroforestry in the arid zone of India. The experiment was conducted for three years to evaluate the tree-crop interactions as affected by varying tree density (1666, 833 and 417 stems ha^{-1}) and different intercrops, i.e. mungbean, clusterbean, mothbean and pearlmillet. During the tree establishment phase, *P. cineraria* did not compete with the associated agricultural crops nor was its growth affected by the intercrops. At four years of age, 417 stems ha^{-1} (4 m x 6 m spacing) was found to be the optimum tree density (Gupta *et al.*, 1998). Similar result was also found in case of *Eucalyptus grandis* at the time of establishment which did not affect the intercropped with beans (*Phaseolus vulgaris*). The production of intercropped beans was higher than monoculture beans, indicating the presence of

complementary interaction (Couto and Gomes, 1995). The yield potential of intercrops with forest tree species revealed that the grain yield of agricultural crops (intercrops) decreased when it was grown in association with tree as compared to sole crops. The reduction in yield under *Casuarina* was more thane *Adina cordifolia* and *Gmelina arborea* (Maheta *et al.*, 1996). Tree-crop interaction effect under agrisilvicultural system with twelve MPTS (*Acacia nilotica*, *A. auriculiformis*, *Casuarina equisetifolia*, *Madhuca latifolia*, *Melia azedarach*, *Leucaena leucocephala*, *Dalbergia sissoo*, *Albizia lebbeck*, *Syzygium cumini*, *Eucalyptus tereticornis*, *Emblica officinalis*, and *Hardwickia binata*) was studied during kharif 1988-91. Arable crops were raised in their association. In the first year, no definite trend was noticed in grain production of Kharif and Rabi crops with association of trees versus sole cropping. In the second year the performance of arhar-gram rotation was best in terms of their relative yield (131, 99.5 and 111.6 % for arhar, gram and total production/annum, respectively). The higher grain production was observed in association with MPTS like *Casuarina*, *Emblica* and *Eucalyptus* recording 80-82 per cent relative yield followed by 79 per cent in association with *Leucaena*, *Sissoo* and *Mahua*, respectively (Roy and Gill, 1991). Kushwaha and Mathur (1995) studied the effect of MPTS on yield of agricultural crops in an agroforestry system. The field crops were grown under 8m rows of *Leucaena leucocephala, Eucalyptus tereticornis* and *Moringa oleifera* spaced 4 m apart with 2 m between trees. There were no significant effects on crop yields during the first two years, but in the third year fodder sorghum and mustard yield were reduced. Blackgram grown under *M. oleifera* or *L. leucocephala* gave similar yields to the control. Soybean was found to be unsuitable for growing under these trees. Similarly growing of soybean as intercrop in bamboo plantations in 3 m x 3 m spacing. The productivity of soybean as intercropped was found lower as compared with pure soybean plantation (Shanmughavel and Francis, 2001).

An investigation was carried out to see the effect of *Eucalyptus* on associated seasonal crops. The saplings of *Eucalyptus* hybrid were planted by adopting 20 m x 1m spacing in north-south direction during 1983. Saplings were allowed to grow for five years. At the end of fifth year five seasonal crops viz. pearlmillet, maize, groundnut, pigeonpea and cotton were raised in between *Eucalyptus* tree lines during kharif 1988-89. The extent of adverse effect of *Eucalyptus* was maximum on maize and minimum on

cotton. The yields were significantly higher on western side than on eastern side. The yield increase with every unit increase in distance from tree line was also found significant (Nadagouda *et al.*, 1997). The effect of *Azadirachta indica*, *Prosopis cineraria*, *Dalbergia sissoo and Acacia nilotica* on the yield of irrigated wheat crop was studied under semi-arid regions of Harayna, in Northern India. *A. nilotica* had the most significant and prominent effect, and a reduction of nearly 40 to 60 per cent was observed in wheat yield. The effect of this tree species was observed even beyond the spread of the crown. *Dalbergia sissoo* reduced yield by 4 to 30 per cent but the reduction was only up to a distance of 3 m. In general, the impact of trees on wheat yield was observed up to 3 m distance and a little impact of tree was observed up to 5 m distance and almost no impact at 7 m distance (Puri and Bangarwa, 1992). In Chhattisgarh area presence of *Acacia nilotica* as scattered trees inside crop fields at high densities (100-125 trees ha^{-1}) on a 10-12 year rotation is very popular as traditional agroforestry of the region. Impact of *A. nilotica* trees on associated rice crop, was monitored in a field at Bilaspur during 1993-94. The results indicated that trees did not significantly affect growth and yield parameters, excepting grain yield. Grain yield was reduced to the extent of 28-30 per cent immediately below the canopy of trees and grain yield gradually increased away from spread of crown (Viswananth *et al.*, 1998).

In *Azadirachta indica* based agroforestry system at NRCAF, Jhansi. It was observed that, in general, neem trees depressed the intercrops (blackgram) yield and yield components. Depressing effect was more near to the tree base compared to away from the tree. Maximum competitive effect (53-64 % reduction) was observed on grain yield, although the seeds of blackgram were bold which reflected the higher test weight near to the tree base (Pandey *et al.*, 1999).

In a 10-year-study at Doon valley on a silty clay-loam soil with *Grewia optiva, Morus alba* and *Eucalyptus* hybrid with rice-wheat rotation, wherein tree were planted at 5m apart. It was observed that all the tree species had depressing effect on crop yield. The yield of crop was significantly affected with respect to distance from tree line. *Eucalyptus* yielded 32 tonnes ha^{-1} of wood after 10-year-rotation (Khybri *et al.*, 1988). In hedgerow plantation of *Leucaena leucocephala* with maize, blackgram and clusterbean at

Chandigarh, there was an average reduction of 38, 34 and 29 per cent in the yield of maize, blackgram and clusterbean, respectively compared with pure crops when grown as intercrops with *Leucaena*. This reduction in yield of crops was compensated by relatively higher fodder and fuel production of *Leucaena*. Maximum returns were obtained when *Leucaena* was intercropped with clusterbean and blackgram compared with growing of pure *Leucaena* or crops (Mittal and Singh, 1983).

In the foothill (tarai) areas of Utter Pradesh, the agroforestry practices are popular; for example trees as woody perennial with *Mentha spp* and *Cymbopogon spp* as non-conventional crops showed promising trends for first year. However, the herb and oil yields of *Mentha spp* decreased during the second year, whereas the yield of *Cymbopogon spp* did not increase or decrease during the second year or thereafter (Singhal and Yadaya, 1994). In an another observation, 20-year-old *Eucalyptus tereticornis* tree lines in a clay-loam soil of Kota had an adverse effect on yield up to 10 m distance in rainy-season crops and 20 m distance in winter season crops. The average yield reduction in rainy-season crops was 36, 54 and 55 per cent in sorghum, greengram and blackgram, respectively. In winter season, the reduction in yield was 82 and 64 per cent in safflower and taramira respectively. Sorghum was found more compatible than pulses in rainy season and taramira performed better than safflower in winter season (Prasad *et al.*, 1985). In an exhaustive study, *Prosopis cineraria* and *Acacia albida* were grown under semi-arid region at three spacing (5 m x 5 m, 10 m x 10 m and 5 m x 10 m) with greengram and clusterbean. It was noticed that seed production of greengram and clusterbean was not affected by *Prosopis* or *Alcacia albida* up to second year. But during third year, clusterbean yield was adversely affected by *A. albida* and *P. cineraria* had no adverse effect a grain yield (Shankarnarayana and Harsh, 1986).

The relative influence of above and below ground competition on the growth and productivity of *Linum usitatissimum* was studied in a *Leucaena leucocephala* based alley cropping system at a sub-humid site in central India. To examine the relative impact of above and below ground competition, three competition situations were created; crop + *Leucaena* shrub neighbour, crop + *Leucaena* hedge neighbour and sole crop in 4 m and 8 m alley-sizes. The above ground biomass and grain yield of the crop were reduced by 9

to 37 per cent and 17 to 26 per cent, respectively in crop+hedge treatment and 64 to 98 per cent and 89 to 96 per cent, respectively in crop+shrub treatment compared to that of sole crops (Pandey *et al.*, 2001).

The influence of single row plantation of *Eucalyptus tereticornis* and *Populus deltoides* on the yields of wheat varieties (HD-2285 and WH-542) was assessed during winter seasons of 1994-95 and 1995-96. The effect of *Eucalyptus* belt on the yields of wheat varieties HD-2285 and WH-542 was found negative up to 11 m and 13 m from tree row respectively. However, *Populus* windbreak affected the yields of both the wheat varieties up to 11 m distance except straw yield of WH-542 (7 m). A strong direct negative correlation was noticed between the parameters studied and the distance from the tree line. *Eucalyptus* tree belt had more adverse effect on wheat varieties than the *Populus* tree belt (Anil kumar *et al.*, 1998). Similarly Singh *et al.* (1993) has also examined grain yield potential three varieties of wheat, viz. PBW-222, HD-2329 and PBW-34 under six-year-old popular plantations. The order of yield reduction was; PBW-34 (57.1 per cent) > PBW-222 (19.4 per cent) > HD-2329 (15.3 per cent). A significant yield reduction was found in which under popular plantation as compared to crops grown in open condition.

In a field study the effect of *Acacia tortilis* was evaluated on the row-wise yield of different intercrops at Dantiwada (Gujrat). The first two rows registered the maximum yield, which was probably due to availability of large space to the crop. There was in general no difference in the yield of other rows. Since, the rows adjoining the trees did not register a lower yield as compared to other rows, it appeared that *A. tortilis* did not produce any adverse effect on the intercrops. On a hectare basis, a slight reduction in the yield of intercrops was observed as compared to that sole crops. This appeared due to lesser area available for the crops due to inclusion of tree component. However the differences between intercrops and that sole crops was not found significant. Among the different arable crops, clusterbean had given the highest total income. It was at par with castor and significantly superior over rest of the crops (Anonymous, 1986). Similarly finding was also reported by Shankarnarayana and Harsh (1986) in case of *Prosopis cineraria* and *Acacia albida* with greengram and clusterbean crop up to two years. But

during third year, clusterbean yield was adversely affected when it was grown with *A. albida* and *P. cineraria* had no adverse effect on either greengram or clusterbean.

2.2 Weed population

The weed problem is a very common phenomenon in cultivation of crops under all agro-ecosystems. The problem, in particular, is so far more difficult to manage in tree-crop system, because at the time of preparation of field or intercultural operation, some space left over near by the tree or in tree line, where weeds exist regularly. Weeds are also responsible for competition (negative interaction) with arable crops because they also share growth resources at same level. Therefore, it is necessary to know the weed population in the crop stand for evaluation of complementary or competitive effect in tree-crop system. Although the early canopy forming crops are known as smother crop to weeds. When two or more crops are grown together as intercrops, the total weeds suppressing ability of a system will be higher than the sole cropping and thus provides an opportunity to utilize crops themselves as a tool of weed management (Rao and Shetty, 1976). The intercropping practices of arable crops between the rows of trees (agroforestry) are also widely prevalent in India. Multi-storied cropping is extensively practiced in plantation crops raised in south and north-east India, to exploit sunlight, soil moisture and nutrients to the maximum extent without sacrificing the yield of main crops.

A reduction of weeds due to the presence of trees has been reported from many ecological zones. In alley cropping systems in Nigeria, Yamoah *et al.* (1986) found that weed yield was positively correlated with available radiation. *Cassia siamea* was reported to control weeds better than *Gliricidia sepium* or *Flemingia macrophylla*. In an alley cropping trial in Costa Rica, Rippin (1991) reported a reduction of weed biomass of over 50 per cent in alley of *Erythrina poeppigiana* and *Gliricidia sepium* as compared with non alley cropped plots, although the mechanism involved was not clearly established. Szott *et al.* (1991) reported that weed suppression by prunings in alley cropping was related to mulch quality slowly decomposing mulches such as *Inga* suppressed weeds more effectively than mulches that decomposed more rapidly.

A field study was initiated during winter season of 1998-99 at Pantnagar to identify the prospectus of growing wheat (*Triticum aestivum* L) under *Eucalyptus tereticornis* to produce more grains and for effective management of weeds. The average reduction of 5.6 per cent in grain yield was recorded in sole crop without trees compared with the intercrop grown at the tree orientatrion of 168-192^0 in which the maximum weed control efficiency and highest grain yield of intercrop wheat was observed under 10-year-old *Eucalyptus* trees. Density and dry matter accumulation by weeds as recorded at 60 and 90 days after sowing was significantly reduced in all the tree orientation treatments compared with that of sole crop (Tripathi *et al.*, 2002). A reduction up to 90 per cent in weed biomass was observed under *Leucaena leucocephala* alley cropping with varying alley with (2 m, 4 m and 8 m) and within row spacing combinations when compared to crop only (control). An increase of 24 to 76 per cent in maize yields of alley cropped plots compared to the crop-only control was also recorded. The 2 m-alley width closed canopy faster than the 4 m and 8 m, and hence realized highest weed biomass reduction during the short-fallow period between two cropping seasons (Jama *et al.*, 1991).

2.3 Effect of management practices (Pruning, soil barrier and irrigation)

The management practices maximize the production of the desired products through minimizing competition for growth resources among the tree-crop component. For example, pruning of trees in alley cropping and applying pruned biomass in to the soil will automatically increase the growth of the associated intercrop by providing green manure and by allowing more light to penetrate to the crop. While the removal of some parts of the tree or all the crown will obviously reduce the competition ability of tree because, crown management will facilitate more light to under story crop, and reduce demand of moisture and nutrients. Therefore, management practices are very necessary to get optimum production from a tree-crop system. In other hand, the faulty tree management technique can lead not only to lower yields, but trees will die-perhaps the loss of entire planting because every tree species have different growth behavior under different soil and climate. According to adaptability of a particular tree species in particular soil and climate, need to manage their canopy under tree-crop/grass system. The reduction in the competitive ability of the trees, by pruning, was probably vital

allowing the crop to take advantage of the higher nutrient availability under the alley cropping system (Haggar and Beer, 1993).

Management of trees component in agroforestry system at suitable age and interval is of vital importance to get biomass production of under story vegetation, which influenced by the light infiltered through the tree canopy. Light is the principal limiting factor for the growth of under story vegetation as the light penetration decreased with the increased standing density of trees (Acciaresi *et al.*, 1994). The forage yield of grasses is directly proportionate to the photosynthetic active radiation (PAR) falling through the tree canopy (Shukla and Hazra, 1994). Viswananth *et al.* (1998) suggested that timely root and crown pruning was well as thinning practices to ensure higher crop yields.

2.3.1 Pruning

Pruning is cutting of branches or even young stem. It helps in minimizing shade effect on intercrops and to maintain the quality of timber, fruit etc. Many workers Dijkman (1950), Das and Dalvi (1981), Osman (1981), Pathak *et al.* (1981), Pathak and Patil (1982), Duguma *et al.* (1988) have reported the effect of height and intensity of pruning on the biomass production. Solanki and Ram Newaj (1996) reported that pruning of MPTS during each year reduce the competition with crops and produced good amount of biomass and compensated the reduction of grain yield due to competition.

The effect of pruning practices in *Albizia lebbeck* and their influence on the yield of sunflower was studied in a rainfed Alfisol. Results revealed that during first year of experimentation, there was no significant yield loss in sunflower crop due to tree component. However, during second, third and fourth years, the narrow spacing (4 m x 4 m) adopted for trees had significant negative influence on crop growth. The results also proved that due to pollarding of trees at a height of 1.5 m from the ground, the negative impact of trees could be avoided and sustainable advantage can be derived from *A. lebbeck* based agri-silvi system (Joseph *et al.*, 1999). Ralhan *et al.* (1992) also reported in an agrisilvicultural system, pruning after third year permitted some recovery in yield of intercrop, similarly topping at 1.50 m of subabul canopy, gave significantly more yield of

clusterbean and sesame grown as under story crops and better quality of produce (Thenua *et al.*, 1999).

Droppelmann *et al.* (2000) reported the effect of two different *Acacia saligna* tree, planting densities (2500 and 833 tree ha^{-1}) tree pruning (no pruning Vs. pruning) and annual intercrops (no intercrop Vs. intercrop) on total biomass production and their interactions. *Sorghum bicolor* was used during the first vegetation period and *Vigna unguiculata* during second. High biomass production (>13 t ha^{-1} over a two year period) was observed irrespective of intercropping of pruned trees or sole tree stands. Although the pruning treatment reduced total tree biomass yields by a quarter, the introduction of annual intercrops after the pruning of trees outweighed this loss. The yields of the intercrops in the pruned tree treatments were similar to their yields when grown as monocrops. The calculation of LER showed over yielding for intercropped, pruned systems. The high values for LER indicate that there is complementarity in resource use between the different species. The pruning of 10 years old plantation of three MPTS, (*Hardwickia binata, Anogeissus pendula* and *A. latifolia*) with different pruning intensities (10, 25, 50 and 75 %) indicated that pruning has a significant effect on the intercrop (blackgram) yield. The maximum benefit of grain yield was recorded with 75 per cent pruning (Handa and Rai, 2001-2002).

Munna Ram *et al.* (2000-2001) studied with three tree species viz. *Albizia procera, Azadirachta indica* and *Tectona grandis,* two tree management practices (pruning up to 50 % of height and unpruned). Blackgram and wheat were raised as intercrops. During fifth year the yield of wheat and blackgram got affected under the canopy of all the tree species over control but the effect was more pronounced under *A. procera*. Minimum decrease in wheat and blackgram yields were recorded in association with *T. grandis*. Pruning has positive effect on crops yield and differed significantly but did not differ from each other within the species. The combined effect of species vs pruning was found significant only in blackgram. Crop plants grown with pruned trees attained higher dry matter and leaf area index than those with unpruned trees (Osman *et al.*, 1998).

Paroda and Muthana (1979) reported that 8 year old plantation of *Holoptelea integrifolia* grown at 5 m x 5 m spacing, seed and dry matter yield of greengram and clusterbean were minimum under unlopped situation and the yield improved under lopped trees. The production was maximum where tree component was absent. Different canopy management treatments in 5-year-old *Morus alba* trees significantly affected growth and yield potential of urd (*Phaseolus mungo*) and pea (*Pisum sativum*), both on north as well as south of the tree trunk (Thakur and Singh, 2002).

2.3.2 Soil barrier

Knowledge of the root distribution of trees is essential to understand the ecological niche of a tree species, to design agroforestry system and its management of optimize the productivity of trees and crops in various agroforestry systems (Huxley, 1983; Von Maydell, 1987; Toky *et al.*, 1989). Once competition is observed between tree and crop, it can be minimized by limiting the components, by harvesting them at appropriate time and/or by some management practices (pruning, trenching, root barrier etc.). Mostly the researchers for quantifying the competitive effect in tree-crop system have used soil barriers. However, they can also be used to prevent interaction between plots. The most commonly used root barriers/soil barriers are polythene sheets, galvanized iron sheets, root exclusion mesh and fibreglass. Asbestos sheets or brick walls can also be used.

The competition for soil moisture in tree-crop system is responsible for the negative interactions in the semi-arid tropics. The below ground interactions can be separated by a shallow polythene barrier (0.5 m) and the presence of a root barrier was effective in restricting lateral movement of the roots (Ong *et al.*, 1991). The impact of root barrier under *Leucaena leucocephala* alley cropping system on intercropped sorghum or cowpea was small as compared to the pruning of *Leucaena* hedge (Osman *et al.*, 1998). For studying the rooting behaviour and distribution of fine roots of five tree species viz. *Bauhinia purpurea, Grewia optiva, Eucalyptus tereticornis, Leucacena leucocephala, Ougeinia oojeinensis*, the roots were exposed at the time of planting 6 months, 16 months and 28 months after planting. Total root weight and root volumes were highest in *E. tereticornis* and lowest in *B. purpurea*. Major part of the root system

confined within 90-120 cm soil depth in case *B. purpurea, Grewia optiva and L. leucocephala* but *E. tereticornis* and *Ougeinia oojeinensis* strike their roots to deeper depths. *B. purpurea* had its roots evenly distributed down to 120 cm. The study indicates that bulk of the roots of the five tree species are found near the surface but observation on soil moisture and nutrient content does not indicate variation under the tree canopies and in open. Hence there may not be root competition in initial years of plantation (Dhyani *et al.*, 1990).

Singh *et al.* (1989) observed the below-ground interaction by installing a polythene root barrier in *Leucaena* based alley cropping system. The cowpea, castor and sorghum were grown as intercrop to study the interaction effect between alleys and crops. Growth and yield of crops declined from 150 to 30 per cent of sole crop as the distance from the hedgerows decreased from 5 to 0.3 m. The presence of the root barrier had a marked effect on crop growth and completely eliminated any reduction in crop yield. Similar results were obtained in an alley cropping system with *Cassia siamea* and *Leucacena leucocephala* in Togo, where the roots were cut biweekly to ploughing depth, the growth of maize plants close to the hedgerows was less reduced than in treatments without root cutting (Schroth, 1989). Corlett *et al.* (1992) also observed that when root competition between tree and crop components was reduced by a polythene barrier (up to 50 cm depth) the intercropped millet grew taller eventually matching *Leucaena* hedge in height and partially escaping the shading and yield reduction experienced in the alley cropped millet without barrier.

The effect of intercropping and tree pruning were investigated on root distribution and soil water depletion in an alley cropping system with *Acacia saligna* and *Sorghum bicolor* in northern Kenya. The trial was established in 1994, with the tree rows at 4 m x 1 m spacing; trees were pruned in March 1996 and the biomass removed for use as fodder. Sorghum was planted at 50 cm x 25 cm spacing between the tree rows, twice in 1995 and once in 1996. Root distribution was determined by destructive sampling. The highest root length density was always measured in the topsoil, regardless of season or cropping system (tree or crop alone, or intercropped). In the dry season, the proportion of roots under the tree row compared with the alley was higher than during the wet season;

the same was found for the proportion of roots in the subsoil compared with the topsoil. Pruning decreased the total root length density of sole cropped trees by 47 per cent. The highest root length density was found when the pruned trees were intercropped with sorghum. If the trees were not pruned, combining trees and crops did not increase root length density. Intercropping resulted in a spatial separation of the root system of trees and crops between the hedgerows, sorghum having more roots in the topsoil and the trees having more roots in the subsoil under alley cropping than in monoculture. At the hedgerow, however, the root systems of trees and crop overlapped and more roots were found than the sum of roots of sole cropped trees and crops (Lehmann *et al.*, 1998)

Ram Newaj *et al.* (2001) examined the impact of different root management practices (deep ploughing, root barrier-polythene sheet, deep basin, pruning up to 40 % height and control) on rooting pattern of *Dalbergia sissoo* under agrisilvicultural system. Among all the root management practices, deep ploughing and deep basin exhibited significantly lower root density at different places (0.5, 1.0, 2.0 and 3.0 m) from tree base compared with the pruning, root barrier and control. Specific root length shows a similar trend at different distances (0.5, 1.0, 2.0 and 3.0 m) from tree base. In general, the specific root length was lower in 15 cm-top soil layer near by the tree base and it increased sharply with increase of distances from tree base in all the management practices. The value of specific root length was higher in deep basin and deep ploughing at all the places from tree base. Root biomass in upper 15 cm soil layer under deep basin was significantly lowest at 0.5, 1.0, 2.0 and 3.0 m away from tree base compared with deep ploughing, pruning, root barrier and control. The upper 30 cm soil layer contained maximum roots (76 to 84 %), 30-45 cm soil layer (8.75 to 13.12 %), 45-60 cm soil layer (5.25 to 9.48 %), 60-75 cm soil layer (1.0 %) and in 75-105 cm soil layer the roots were negligible. Several scientists (Sharma, 2000; Toky and Bisht, 1992; Singh and Dayal, 1979) were also reported that elimination of tree roots help to increase the yield of intercrops.

Dadhwal *et al.* (1986) studied the effect on root distribution of eight years old *Eucalyptus hybrid* trees standing in east-west direction on field boundary and their impact on rainfed maize (var. Ganga-5 during 1984 kharif and desi maize in 1983 kharif) and

wheat (RR-21). The *Eucalyptus* trees on the field boundary have a mean dbh of 50 cm and mean height 14.1 m. The tree root competition in the surface 1 m depth (as observed from those obtained from a unit volume of the trench) consisted up to 47 roots more than 10 cm per diameter; 48 of 2.5 cm per diameter and numerous roots of less than 2 cm per diameter. These roots would have entered the agricultural field in 12.5 m long segment, had there been no trench to eliminate them.

2.3.3 Irrigation

Availability of adequate quantities of soil moisture and nutrients is essential for successful growth and development of plants. In agroforestry system, the root system of the crops are usually confined to upper soil layer that are also shared by the tree roots, but the trees can also exploit soil moisture beyond reach of the crops. Therefore, the competition for moisture and nutrient is generally more severe for the crop components when the requirement of these resources to tree components will be more. The degree of competition for moisture and nutrients depends on the tree and crop species, their density and the age of trees. Water competition is likely to play a major role in the productivity of agroforestry systems, especially in dry areas (Malik and Sharma, 1990). In alley cropping trials of *Leucaena leucocephala* with cowpea, castor and sorghum under semi-arid conditions of the India, the effect of competition for water was more severe than shading effects. The yields of cowpea, castor and sorghum were declined from 15 to 30 per cent as the distance from the hedge rows of *Leucaena leucocephala* decreased from 5 to 0.3 m. Castor was more affected by the hedgerows compared to cowpea and sorghum. The yield of crops decreased consistently and progressively as the age of the tree increased. The reduction in the crop yield in case of wider row spacing (7.2 m) was relatively less for the same age of the tree as compared to narrow spacing of 3.6 m (Singh *et al.*, 1989).

Soil moisture studied conducted at CAZRI, Jodhpur have shown that tree which are usually deep rooted and grasses which are shallow rooted can co-exist on the same site as fuel and fodder plantation without detriment each other (Gupta *et. al.*, 1975). The organic matter added by trees to the soil increases water holding capacity and the shade of trees reduced the evaporation resulting in higher soil moisture near trees. In alley

cropping study under semi-arid conditions of Zambia, the soil moisture content was higher under the hedge rows of *Leucaena leucocephala* and *Flemingia macrophylla* than in maize rows during dry period, indicating no apparent competition for moisture between the hedge rows and the maize plants (Chirwa *et al*., 1994). Similarly, higher soil moisture under *Prosopis cineraria* trees in arid regions of the India was also reported by Puri *et al.* (1994).

Pant and Singh (1998) studied in an agroforestry system was conducted to study the water table and soil moisture distribution below *Populas deltoides, Eucalyptus hybrid, Syzygium cumini* and *Trewia nudiflora* trees intercropped with wheat and urd. Water table depth ranged between 85 cm under tree (July-August) to 117 cm in open (May-June) thereby a deep water table was recorded in the month of June and a shallow in August. Soil moisture was significantly higher under trees as compared to open showing an increasing trend with the depth and a decreasing trend with the season. Suresh and Rao (1999) studied the three-nitrogen fixing tree species viz. *Faidherbia albida, Acacia ferruginea, Albizia lebbeck* on intercropped rainfed sorghum was investigated at Hyderabad. The trees were established in shallow alfisols during 1985 with a spacing of 4 m x 4 m. Intercropping was done in 1993 and 1994. Soil moisture status was more favourable under *F. albida* than under the other tree species. Soil moisture at all stages of crop growth was more in sole crop situation.

Soil water depletion was higher under the tree row than in the alley and higher in alley cropping than in mono-cultural systems. Water competition between trees and crop was confirmed by the carbohydrate analysis, which showed lower sugar contents of roots in agroforestry than in mono-culture. The agroforestry combination used the soil water between the hedgerows more efficiently than the sole cropped trees or crops, as water uptake of the trees reached deeper and started earlier after the flood irrigation than that of the sorghum, whereas the crop could better utilize topsoil water. Under the experimental conditions, the root system of the alley cropped *Acacia* and Sorghum exploited a larger soil volume thus utilizing soil resources more efficiently than the respectively mono-cultures (Lehmann *et al*., 1998).

Sanjay Kumar *et al.* (2001) conducted a study at NARP farm, Balsamand, CCS HAU, Hisar to evaluate the effect of trenching on soil moisture extraction pattern by twenty-year-old *Acacia tortilis* trees. A trench 1.5 m deep, 0.5 m wide and 30 m long was excavated on south and parallel to east-west side at a distance of 2 m from the tree line of block plantation. Pearlmillet was taken as a test crop beyond the trench. Soil moisture content at different depths (0-1.20 m) at a distance of 10 m and 20 m normal to tree line under two conditions viz. with trench and without trench at different times after a heavy rainfall (76 mm) were determined by gravimetrically. It was found that the soil moisture content increased with depth in all the cases. The rate of increase in amount of water extracted from 0-1.20 m profile was appreciably less in trenching treatment than that under without trenching treatment; the rate remained constant with distance, whereas, it was 27 per cent higher in 10 m as compared to that in 20 m under no-trench treatment. The amount of water content in 0-1.20 m was on an average 52 per cent higher in trenching than under no trenching treatment when time and distance factors taken together. It was observed that the grain yield of pearlmillet from 30 m x 15 m plot under trenching treatment was 68.3 per cent higher than that under no-trenching treatment.

2.4 Microclimatic changes due to tree

The term microclimate also refers not only to the climatic factors in the air layers near the ground, but also to those beneath the soil surface. In agroforestry systems, microclimate amelioration involving soil moisture and soil temperature relations results primarily from the use of trees for shade, or as live supports, live fences, or windbreaks and shelterbelts. The provision of shade cause a net effect of complex interactions, which extend far beyond the more reduction of heat and light (Willey, 1975). Temperature, humidity, and movement of air, as well as temperature and moisture of the soil, directly affect photosynthesis, transpiration, and the energy balance of associated crops, the net effect of which may translate into increased yields (Rosenberg *et al.*, 1983). The innumerable practices that traditional farmers have developed to attain this goal attest to the importance attributed to microclimate management (Wilken, 1972; Stigter, 1988; Reifsnyder and Darnhofer, 1989). Trees in agroforestry systems are capable of increasing the relative humidity and increasing the day temperature of the area. Trees reduce the

impact of rainfall as about 25 to 30 per cent of the rainfall is intercepted by the tree crown, and 10-15 per cent of the rainfall reaches the ground as stem flow. Thus, only about 50 to 60 per cent of the rainfall come to the ground directly. Microclimatic changes due to tree may influence its neighboring species, not only adding or removing of some factor, but by altering the balance between beneficial and harmful insect. The extent of microclimatic changes due to trees has not been properly investigated under different conditions. Several variables, such as amount of radiation, temperature, relative humidity and soil water potential have received maximum attention in agroforestry investigations

2.4.1 Light interception

Sun is the prime source of energy for food production. The interception of solar radiation by terrestrial system and its modification determines weather and climate. In multiple cropping systems, especially in an intercropping sysetm involving trees/shrubs and agricultural crops can increase the capture and/or conversion efficiency of light by each of the components. The productivity of a crop must ultimately depend upon its capacity to utilise solar energy. In agroforestry system tree reduced the availability of light to the intercrop due to lower interception of light compared to open situation (Basavaraju *et al.*, 2001; Maheta *et al.*, 1996; Suresh and Rao, 1999). The amount of photosynthetically active radiation intercepted from the canopy of the trees are varied from tree species to species and solar radiation appeared to be most important factor for the growth and yield of crops (Tomar *et al.*, 2000; Suresh and Rao., 1999; Hazra and Tripathi, 1989; Kumpawat and Rathore, 1994; Misra and Bhatt, 1991; Bhatt *et al.*, 1994).

Kiran and Agnihotri (2001) investigated the effect of modified micro-climate conditions on the yield and yield attributes of wheat during 1996-97. Wheat was intercropped with *Dalbergia sissoo* (planted in 1989). Tree rows were pruned 0, 30, 45, 60 and 90 per cent, respectively, in anticlock wise direction. Net radiation available during grain filling and maturity stages ranged 70-75 and 58-77 per cent over control during crop growing period.

Microclimatic elements depend upon the tree canopy structure and their density, if tree density will increase or decrease the values of light interception, relative humidity,

temperature will also be varied accordingly (Behari *et al.*, 1994 and Anonymous, 2000-2001). The relative influence of above and below ground competition on the growth and productivity of *Linum usitatissimum* was studied in a *Leucaena leucocephala* based alley cropping system at a sub-humid site in central India. To examine the relative impact of above and below ground competition, three competition situations were created: crop + *Leucaena* shrub neighbor, crop + *L.* hedge neighbor and sole crop in 4 m and 8 m alley-sizes. Sunlight did not differ in crop + hedge treatment compared to that in sole crop plot, whereas, it was reduced by 36 to 82 per cent, across the alley sizes, in crop + shrub treatment compared to that of sole crop plot. Moreover, reduction in sunlight was greater in 4 m alley (Pandey *et al.*, 2001).

The effect of pollarding and no pollarding of subabul on light infiltration and growth of two pasture species (*Cenchrus ciliaris* and *Stylosanthes hamata*) was indicated that under pollareded trees, in general, light infiltration was more than double as compared to non-pollared trees. The above ground dry biomass of both *C. ciliaris* and *S. hamata* was more under pollarded trees than under non-pollarded ones. However, pollarded plots recorded less than 36 per cent biomass of open plots (Anonymous, 2001-2002).

2.4.2 Temperature and humidity

In general, shading causes a reduction of temperature and temperature fluctuations as well as the vapor pressure deficit. Soil temperature is one of the important environmental factors of plant growth and development. The exchange of heat between the soil and its surface has pronounced effect on diurnal surface temperature variations. The nature and quantum of this exchange is primarily governed by the heat capacity per volume and thermal conductivity of the soil, both of which vary with the nature of the soil surface and its moisture content.

Atmospheric moisture plays a significant role in weather climate. It is a factor in humidity, cloudiness, precipitation and visibility. Water vapor and clouds affect transmission of radiation both to and from earth's surface. Atmospheric water gained by evaporation is lost by precipitation.

Trees change the microclimate to it neighbors for examples in a shelterbelt network of *Populus bolleana* Wulanbuhe (Nei Menggu) at China, the temperatures in the windbreak area decreased by 0.4-0.6 ^{0}C, with layer decreases (1.2 ^{0}C) in July (the hottest month). Evaporation rate decreased by 24.3-24.7 per cent, relative humidity increased by 8-15 per cent, and days of desiccating hot wind decreased by 58.8 per cent (33.3 % near light windbreaks) under 2 m x 8 m spacing and 87.5 per cent near more dense types in 2m x 1m spacing (Yuguang, 1997). Hazra and Patil (1986) observed that the tree covers maintained higher relative humidity 62-70 per cent as compared to open (56%). A trial in which pearlmillet was grown between hedges of *Leucaena leucocephala* at ICRISAT, Hyderabad. In terms of microclimate, the main advantage of the alley system was to intercept more light throughout the year and therefore to produce more biomass. Temperature and humidity within the alleys differed little from values recorded in the open but wind speed was substantially less (Monteith *et al.*, 1991).

Microclimatic measurements were recorded in 1979-81 by Al-sayed *et al.* (1989) in a wheat and maize fields at 0.5, 1, 4, 8, 12, 16 and 20 m tree height from 8 to 11-year-old *Casuarina glauca* shelterbelts, 10 m–14 m tall, and in the open, in the W. Nubaria region. There were not significant difference in soil moisture content and air temperature or relative humidity between protected and unprotected fields during the growing season. Soil moisture content in protected wheat fields was higher at distances of 0.5 m height or more, but lower closer to the trees. Soil temperature in the shelterd fields was lower, but air temperature was slightly higher. Ramakrishna *et al.* (1981) also observed that morning air temperature below 7 year old *Acacia tortilis* plantation was lower by 0.1 to 0.7 ^{0}C and in afternoon by 0.6 to 2.0 ^{0}C than that recorded in the open. Similarly, the soil temperature at 0.5 cm and 30 cm depth was lower by 10 to 16 ^{0}C and 4 to 5 ^{0}C as compared to the open. The relative humidity was 7 per cent more under trees than the open. The rainfall interception from 20 to 35 mm storms in 13 and 7 year old *Acacia totilis* plantation varied from 23 to 33 and 14 to 19 per cent, respectively. Tree canopy structure and density also control the water availability beneath the tree canopy and thus, play an important role in the successful adoption of agroforestry system.

2.4.3 Shade length

Shade length depends upon the size of the trees and their canopy structure. The movement of shade also depends upon the change in direction of the sun. Shading was found to be more important than below ground competition in an intercropping study with pearl millet and groundnut in India (Willey and Reddy, 1981). Similarly, Verinumbe and Okali (1985) also observed that competition for light was a more critical factor than root competition for intercropped maize between teak (*Tectona grandis*) in Nigeria. In another observation, Kang *et al.* (1981) emphasized that the low yields from maize rows adjacent to *Leucaena* hedgerows was due to shade. Neumann and Pietrowicz (1989) studied the competition in an agroforestry combination of *Grevillea robusta*, maize, and beans in Rwanda and they reported that the shade cast by *Grevillea* appeared more important than other effect of the trees.

Sood *et al.* (1994) studied the performance of Setaria, Setaria+Guinea, Guinea and local grass cultivars under shaded and unshaded environments at the research farm of Himachal Predesh Krishi Vishvavidyalaya, Palampur during 1991-1992. Shaded environment was provided by 15 years old *Albizia stipulata*, *Cedrella toona*, *Prunus padus* and *Melia azadirachta* plantation. Introduction of Setaria and Setaria + Guinea registered almost identical forage yield under unshaded conditions but higher than Guinea and local grass species. While under shaded conditions Setaria out yielded than other grass species, thereby indicating that this species is an ideal choice for introduction in grasslands representing shaded and unshaded environments.

The growth and yield of the arable crops in alley cropping, are affected by the micro-environment created by the aerial and below ground interactions between the tree and crop component. The shade was the main factor affecting the yield of maize grown in association with the hedgerows of *Leucaena*. Because alley cropping altered the micro-climate experienced by the intercropped millet to an extent which depended on its proximity to the hedge, hedge shape and the relative size of the two components. Larger *Leucaena* hedgerow canopies resulted in more substaintial reductions in wind speed and incident light in the alley cropped millet (Kang *et al.*, 1981).

Singh *et. al.* (1980) reported that mean yield of *Chrysopogon fulvus* was reduced to 86.7 per cent under partial shade and recommended that shisham at a spacing of not less than 9 m x 9 m, should be preferred to khair for planting as fuel-wood cum shade tree in grasslands. According to Gupta and Mohan (1979) cowpea, 'arhar' guava and fodder grasses can be successfully grown under *Acacia tortilis*. Chaturvedi (1981) agricultural crops like soybean, maize, urad, moong, mustard, wheat, potato, peas, gram and millets are grown extensively in block plantations of poplars raised by the Forest Department in the Tarai belt of UP. The yield of the crops decreases in second and subsequent years as tree shade increases but wheat can be successfully cultivated up to 5th year.

Materials and Methods

CHAPTER III
MATERIALS AND METHODS

The present study entitled "Studies on tree-crop interaction in *Albizia procera* based agroforestry system in relation to soil moisture, light and nutrients" was undertaken in Research Farm of National Research Centre for Agroforestry, Jhansi (U.P.) during two consecutive years viz. 2000-2001 and 2001-2002. The details of the materials used, experimental procedure followed and techniques adopted are described in this chapter.

3.1 Experimental site and soil characteristics

The soil of the experimental field was *parwa* representing inter-mixed black and red soil group of Bundelkhand regions covered under the order of Alfisol. The soil is medium in texture, moisture retentive and workability. The soil is prone to crust formation following rains and open weather conditions. It fails to sustain plant growth whenever drought spell exceeds 2-3 weeks even under mild evaporation situation. Before starting the experiment, composite soil samples were taken at 0-15 cm and 15-30 cm soil depth and subjected to physico-chemical analysis. The results of soil analysis at initial stage have been given in table 3.1.

3.2 Weather conditions

The site of experimental field is situated at 25^0 $27^|$ North latitude and 78^0 $35^|$ East longitude, 271 meters above mean sea level in the semi-arid tract of central plateau of India. This region receives about 80 per cent the annual rainfall during southwest monsoon. Annual rainfall ranges from 700-1150 mm with a mean value of 958 mm. The potential evapo-transpiration is quite high in the range of 1400-1700 mm with moisture index value of – 40 to –50. The pattern of the rainfall is highly erratic and more than 90 per cent of the total rainfall occurs within 10 weeks between July to mid September accompanied by intermittent long dry spells. The entire rainfall is received in less than 50 rainy days. Winter showers are rare and uncertain. The frequent drought occurs in entire regions. The low rain in the month of June and September is expected once in three years while in July and August once in seven years. Usually, monsoon commences by the last week of June but sometimes is delayed to the first week of July. The active monsoon oftenly withdraws up to the mid of September or up to the end of August.

Mean annual temperature of the Jhansi is generally high with high degree of variation between maximum and minimum temperatures, sometimes maximum temperature in the summer months of May and June touches to 48 ^{0}C which is peak of summer season. Thus, high temperature accompanied with hot wind causes high potential evapo-transpiration. The mean monthly values of meteorological parameters for the two consecutive years of June, 2000 to October, 2002 are appendix I and illustrated in fig. 3.1 to 3.3.

Table 3.1 Physico-chemical characteristics of the soil

Soil characteristics	Soil depth(cm)		Methods and References
	0-15	15-30	
1.Mechanical composition			
(a) Sand (%)	45.20	46.00	Bouyoucos Hydrometer Method (Bouyoucos,1962)
(b) Silt (%)	21.70	22.60	
(c) Clay (%)	31.40	33.10	
Textural class	Sandy clay loam		
2.Soil moisture characteristics			
(a) Field capacity (%)	25.30	25.70	Pressure Plate Apparatus (Richards,1947)
(b) Permanent wilting point (%)	8.30	8.60	Pressure Membrane Apparatus
(c) Available soil moisture (mm m^{-1})	215.00	216.50	Pressure Plate Apparatus (Richards,1947)
(d) Bulk density (g cm^{3})	1.40	1.48	Core Sampler (Piper,1950)
3. Physico-chemical properties			
(a) Soil pH (1:2.5 soil : water ratio)	6.57	6.81	Combined Glass Electrode pH meter (Jackson,1958)
(b) Electrical conductivity(d Sm^{-1} at 25 x C)	0.08	0.06	Solubridge Method (Richards,1954)
(c) Organic carbon (%)	0.51	0.34	Walkley and Black's Rapid Titration Method (Jackson,1958)
(d) Available nitrogen (kg ha^{-1})	153.40	128.01	Available $KMnO_4$ Method (Subbiah and Asija,1956)
(e) Available phosphorus (kg ha^{-1})	15.21	10.84	Olsen's Method (Olsen *et al.*,1954)
(f) Available potassium(kg ha^{-1})	123.01	112.00	Flame Photometer Method (Toth and Prince,1949)

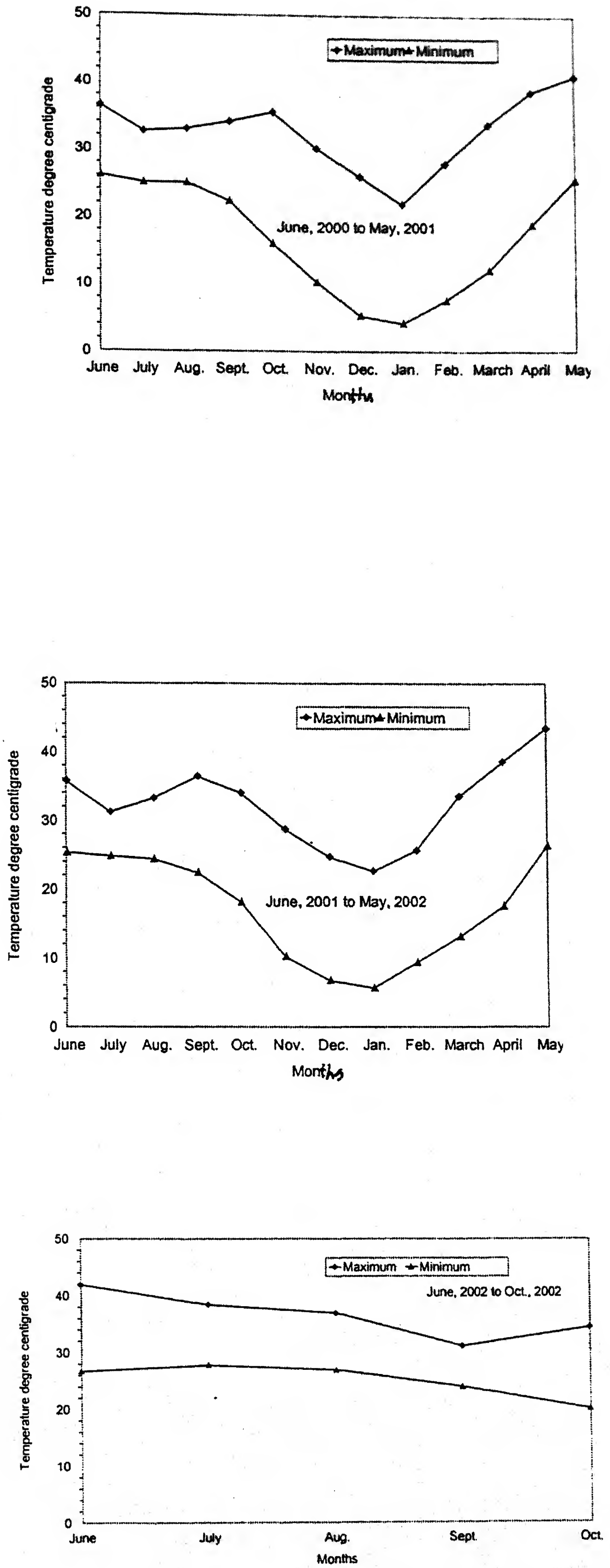
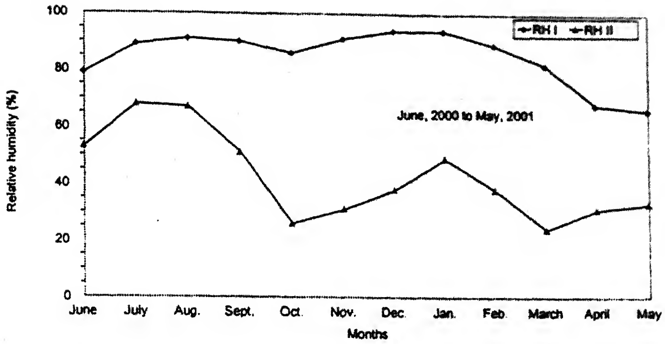
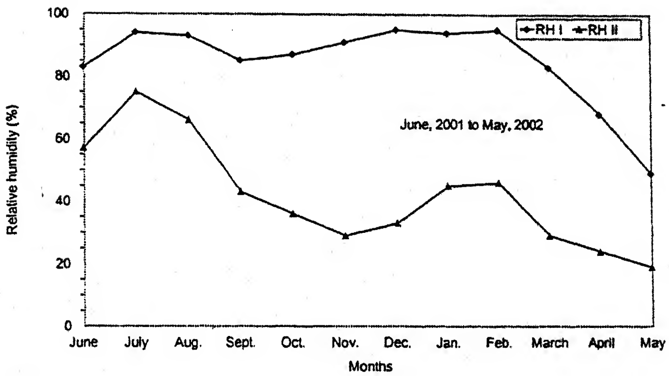


Fig. 3.1 Mean monthly temperature during the experimental period (2000-2002)





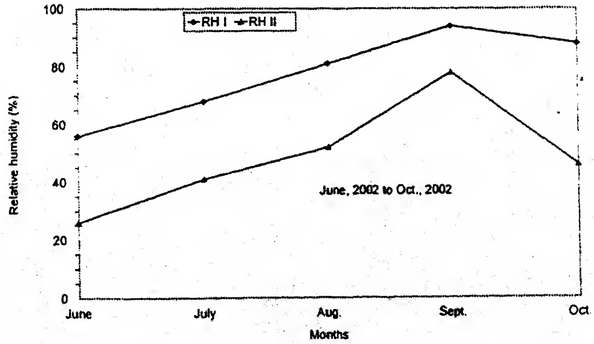
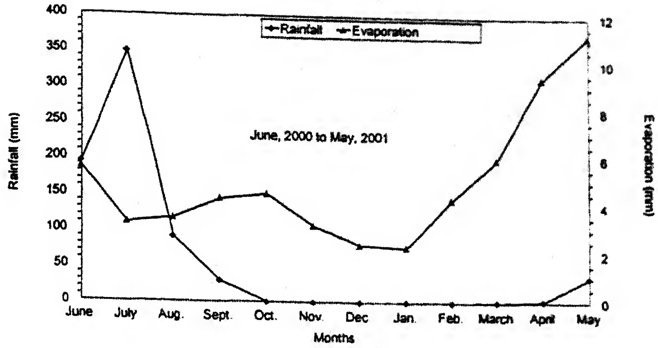
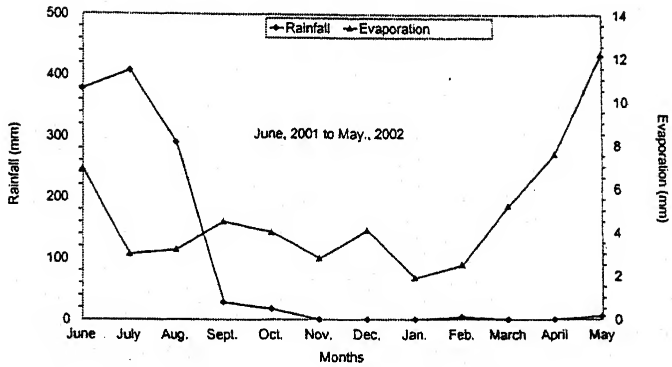


Fig. 3.2 Mean monthly relative humidity during the experimental period (2000-2002)





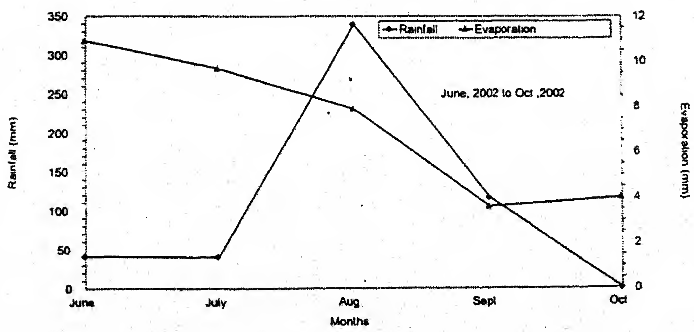


Fig.3.3 Monthly rainfall and mean monthly evaporation during the experimental period (2000-2002)

3.3 Cropping history of the experimental field

Before beginning of this project, the field was engaged for agri-silvi-horticulture experiment.

3.4 Technical programme

3.4.1 Treatments details

1. Planting of tree and allow to grow normally + crop (competition for light, moisture and nutrient)

2.Pruning of tree up to 70% plant height + crop (competition mainly for water, nutrient and minimum competition for light)

3.Treatment 1 + soil barrier (GI sheet will be installed to 1m depth at side between tree and crop) + crop (competition for light only)

4.Pruning of tree up to 70% height + soil barrier + crop (minimum competition for light only)

5.Treatment 1 + irrigation as per requirement of crop (competition for light and nutrient only)

6.Treatment 2 + irrigation same as treatment 5 (competition for nutrient and minimum competition for light)

7. Tree only (control)

8. Crop only (control) irrigated and unirrigated

Tree species: *Albizia procera*

Crop sequence: Blackgram-mustard

Design : Randomized Block Design

Replication : Three

Tree spacing : 8 m x 4 m

Plot size : 288 m^2 (9 tree/plot)

3.4.2 Observations to be recorded

1. Soil moisture depletion pattern at 0-15 and 15-30 cm depth

2. Light interception in selected treatments

3. Micro-climatic parameter during cropping period in every week [shade effect: length (Morning, Noon and Evening) humidity changes (under tree and out side tree canopy), atmospheric temperature changes)]

4. Soil samples in the beginning and at the end of the experiment for organic carbon, pH, electrical conductivity and available N, P and K

5. Root density in selected treatments

6. Growth of the tree (height, collar diameter and crown diameter)

7. Germination percentage row by row / crop height / number of branches / number of pods and siliquae / number of seeds / grain weight of different crops

8. Weeds and their intensity right from sowing to harvesting of crop

9. Crop yield row by row

3.4.3 Field preparation and experimental layout

As per the above-mentioned technical programme, a field was selected for the experiment and the experiment was laid out in randomized block design with three replications. The field was prepared before layout of experiment. The lay out of the experiment have been given in Fig 3.4.

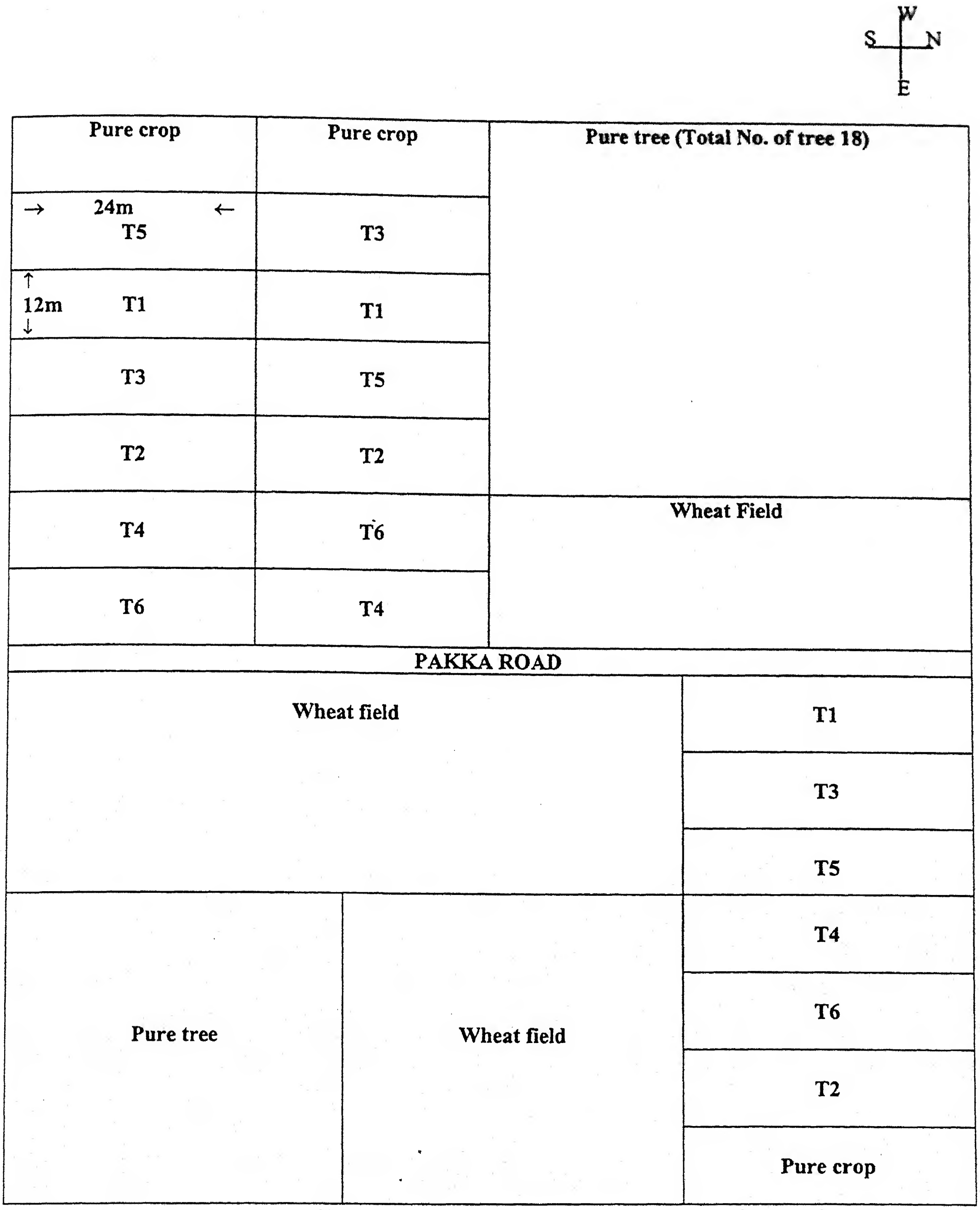


Fig. 3.4 Layout of experiment

Note: Tree = *Albizia procera* Crop = Blackgram - mustard, Plot size 288 m^2 is plot having 9 tree T1 = Planting of tree allow to grow normally + crop T2 = Pruning of tree up to 70 % plant height + crop T3 = T1 + soil barrier + crop T4 = Pruning of tree up to 70 % plant height + soil barrier + crop T5 = T1 + irrigation as per requirement of crop T6 = T2 + irrigation same as treatment 5 T7 = Pure tree T8 = Pure crop

3.4.4 Tree planting

For planting of tree, marking was done at 8 m x 4 m spacing in the end of June, 45 cm^3 planting holes were prepared with the help of post hole auger and refilled with soil + compost + insecticide mixture before onset of monsoon. After onset of monsoon (last week of July, 2000) three months old sapling of *Albizia procera* were planted in the prepared pit.

3.4.5 Root barrier

After planting of the sapling, the root barrier GI sheet 0.6 mm thick was installed around the tree at 0.5 meter away and 1.0 meter in depth in selected treatments (tree allow to grow normally + crop and pruning of tree up to 70 per cent plant height + crop) to separate the effect of below ground interaction.

3.4.6 *Albizia procera* (Roxb.) Benth.

Albizia procera belongs to family leguminosae, commonly called as safed siris and considered as a promising tree for social forestry, agroforestry and wasteland reclamation. This species is distributed throughout sub-himalayan tract, central and south India. *Albizia procera* yields valuable timber and is fast growing tree with nitrogen fixing ability. It has fuel wood with high calorific value and protein rich fodder during dries period. The *Albizia procera* is a termite resistant and grow easily in semi-arid regions.

3.4.7 Blackgram (*Phaseolus mungo* Roxb.)

Blackgram (variety T-9) was sown in present investigation. It matures in 85-90 days. The plants are erect types and seeds are of medium size (40 g per 1000 seed weight) and black in colour. This variety can produce 10-12 q $ha^{-1}$of grain under good crop management conditions.

Blackgram was sown on 6^{th} and 20^{th} of July 2001 and 2002, respectively and 12 kg seed per hectare was used. The crop was sown at 30 cm apart and provided 20 kg nitrogen and 40 kg phosphorus per hectare as basal dose. Before sowing of the crop, seed was treated with fungicide (Thirum 1.5 + Bavistin 1.5) per kg seed and rhizobium culture

@ 5g per kg of seed to avoid any seed born diseases and increase the nitrogen fixation. Thinning and weeding was done after 20 days after sowing.. To control the yellow mosaic virus spraying of monocrotophos 36 per cent SL @ 500 ml ha^{-1} was done twice within 15 days interval.The harvesting of crop was done manually on 3rd and 9th October 2001 and 2002 and the yield of crop was recorded row by row as well as whole plot.

3.4.8 Mustard (*Brassica juncia* Coss.)

Mustard variety varuna was sown in the experiment. It matures in 125-130 days. The plants are tall and semi spreading type. The seed are bold, brownish-black in colour and 4.6 to 5.5 g per 1000 seed weight and average oil content of 42 per cent. Its yield potential is 18-20 q ha^{-1}. It is suitable for commercial cultivation in Uttar Pradesh.

Mustard was sown during 8th November and 9th of October during 2000 and 2001, respectively at 30 cm row spacing. Plant spacing of 10 cm was maintained by thinning of crop after 20 to 25 days after sowing. Before sowing of the crop, seed was treated with fungicide (Thirum) @ 3g per kg of seed. The fertilizers applied 60 : 40 : 40 kg per hectare nitrogen, phosphorus and potassium, respectively. Half of the nitrogen doses (30 kg) along with full doses of phosphorus and potassium was applied at sowing and half nitrogen was top-dressed at first irrigation of the crop. Seed rate of 5 kg per hectare was used. In treatment tree allowed to grow normally + crop + irrigation as per requirement of crop, pruning of tree up to 70 per cent plant height + crop + irrigation as per requirement of the crop and irrigated pure crop (two-irrigation) was given to crop, first at flowering and second at siliquae formation stage. In rest of the treatments, one-irrigation had given to the crop at 30 days after sowing. Mustard was harvested on 8th March and 17th February during 2001 and 2002, respectively.

Aphid (*Lipaphis erysimi*) is a very serious pest of mustard that is the main limiting factor in cultivation of mustard crop. Both nymph and adult suck the sap of the tender leaves, twigs, stem, inflorescence and pods. Spraying of Phosphamidan (Dimecron) 85 per cent S.L. @ 250 ml ha^{-1} was done to control aphid after one month of sowing.

3.4.9 Growth of the tree (height, collar diameter and crown diameter)

The tree growth parameters were recorded for two years in all the treatments in each replication to know the effect of management practices on the tree growth and simultaneously the effect of crop on tree growth. The height and crown diameter of the trees were presented in meter and collar diameter in centimeter.

3.4.9.1 Height

The height of individual tree in a plot and replication with respect of treatment was measured from the ground level to the tip of the main stem with the help of a measuring tape and meter scale.

3.4.9.2 Collar diameter

Collar diameter of individual tree of each of the plot and replication as per treatments was measured with the help of vernier calliper at 5 cm above ground level.

3.4.9.3 Crown diameter

Crown diameter of the trees was measured with the help of measuring tape. First of all the spread of crown in East-West and North-South direction was marked with a wooden stick at last shoot tip of each direction. The distance between North-South and East-West shoot tip was measured as crown length with measuring tape and crown diameter obtained with using following calculation.

$$\text{Crown diameter} = (D1 + D2) \div 2$$

Where, D1 = Crown length in east-west direction

D2 = Crown length in north-south direction

3.4.9.4 Pruning

In selected treatments (pruning of tree up to 70 per plant height + crop, pruning of tree up to 70 per plant height + soil barrier + crop and pruning of tree up to 70 per plant height + irrigation as per requirement of crop) pruning was done up to 70 per cent plant height during the first week of November every year . Pruned materials (leaf and twigs) were collected to record fresh and dry weight for total biomass of individual tree.

3.4.10 Light interception

Light interception was measured with Lux meter. The intensity of light was measured at different distances from tree base (0.5, 1.0, 2.0, 3.0, and 4.0 m) just above canopy of crop and at ground level at 10am, 12 noon and 3pm. The observations were taken at 15, 30, 60, 90 days after sowing and at harvest in mustard and in blackgram at 30, 60 days after sowing and at harvest in selected treatments (tree allow to grow normally and pruning of tree up to 70 per cent plant height). The light interception by the crop components was expressed in per cent using following formula (Palaniappan, 1985).

Light interception = (Light intensity at top of the canopy of crop – Light intensity at ground level) ÷ Light available to the crop × 100

3.4.11 Microclimate

Micro-climatic parameters like humidity and temperature were recorded with the help of Digital Hygro Thermometer in two situations of treatment viz. trees allow to grow normally and pruning up to 70 per cent plant height irrespective of soil barrier and irrigation given as per requirement of the crop. The above microclimatic characters were recorded during 10 am, 12 noon and 3 pm at different distances from tree base at both the side of tree. The same was also recorded in open to compare the changes in microclimate due to trees in tree-crop system. Similarly the shade length of the trees was also measured in tree allowed to grow normally and pruning was done up to 70 per cent plant height at10am, 12noon and 3pm with the help of measuring tape to see the movement of shade and their length in respect to changing the direction of sun with time so that this factor could be considered in tree-crop interaction.

3.4.12 Soil moisture depletion pattern

The soil moisture depletion pattern at 0-15 and 15-30 cm soil depth at different distances (0.5, 1.0, 2.0 and 3.0 m) from tree base during cropping period (rabi season) at 15 days interval. The soil moisture was recorded by gravimetric method (Kirongo *et al.*, 2002) using following formula.

Moisture % = (Fresh weight of soil –Dry weight of soil) ÷ Dry weight of soil × 100

3.4.13 Chemical analysis of soil

In the beginning and in end of the experiment, soil pH, electrical conductivity, organic carbon, available nitrogen, phosphorus and potassium were analyzed to examine the soil fertility status at initial and changing over a period of time. For this, random soil samples were collected from the whole experimental site at 0-15 and 15-30 cm soil depth, with the help of auger before field preparation. At the end of the experiment, the soil samples were collected from each plot of different treatments and replication at 0.5 m, 1.0 m, 2.0 m and 3.0 meter distances from (center of nine trees) tree base of middle tree at 0-15 and 15-30 cm soil depth. The soil samples were air dried, crushed, and passed through 2-mm sieve and composite soil samples were prepared as per distance, depth and treatment from each replication. Finally about 100 g soil was taken out in labeled polythene bag from each composite sample and placed in laboratory for analysis. The procedure/methodology followed in the soil physical and chemical analysis has been given in Table 3.1

3.4.14 Growth, yield and yield attributing characters of crop

Growth and yield attributing characters were recorded row by row from first to fourth row at tree base (from the base of the center tree of a plot was considered for taking all the data relates to growth, yield and yield attributing characters). The observations related to crop were taken left and right side of the tree base, finally the mean values of these two observations were analysis as per design of the experiment

In case of plant population per running meter, the number of germinated plants were counted in each row at both the sides at 15 days after sowing of crop. For other characters viz. height at harvest, number of branch, number of siliquae per plant, grain per siliqua, grain weight, five plants were tagged randomly from first row to fourth row from tree base at both the side. The grain yield per running meter row by row was recorded at both the side of the tree (tagged plants included). The same method was used in case of blackgram to record growth and yield parameters of crop.

3.4.15 Weeds and their intensity

The number of weed meter^{-2} was recorded at 0.5 m away from tree base at both sides of the tree during the 30 days after sowing and at crop harvest to know the weeds population and their effect on crop yield in respect to tree-crop interaction. The number of weed of individual species were counted and dried for calculating the biomass of weeds of a unit area. The values of dry weight basis was transformed by the formula $\sqrt{X} + 0.5$ to compare the weeds biomass in Kharif and Rabi season.

3.4.16 Root studies

The root studies in selected treatments (tree allow to grow normally + crop, pruning of tree up to 70 per cent plant height + crop, tree allow to grow normally + soil barrier + crop and pruning of tree up to 70 per cent plant height + soil barrier + crop) was carried out after one year of plantation, to observe rooting pattern in above-mentioned treatment. The coring technique was used with a core sampler of 5.0 cm dia and 15 cm length at different distances from tree base (0.5, 1.0 and 2.0 m).

Coring technique

Coring is best ways of study the horizontal spread of roots without scarifying the tree/crop. A core sampler of 0.5 cm-dia and 15 cm length was used for coring. For storing core sampler labeled plastic bucket was used soaking in water for over night. After soaking in water the soil was removed carefully from core and washed with clean water. After complete washing, filter the muddy water with 0.87 mm sieve and sorted out the whole root from water and kept in petri dish to wash again with distilled water.

Separate roots in to live and dead categories based on color and tensile strength. Place live roots on soaking paper for few minutes to minimize the water content and measure the total root length by the root image analysis system. After measuring the root length, keep the samples for drying in oven at 70 ^{0}C up to one hour. After drying, weigh the samples to calculate the root length density and specific root length. Following formula was use to calculate root length density and specific root length.

Root length density = cm root length ÷ cm^3 soil volume

Specific root length = meter root length ÷ gram dry weight of root

3.5 Statistical analysis

The statistical analysis of various data collected during the time of experimentation was done on the pattern of randomized block design by applying the technique of "analysis of variance" as advocated by Fisher (1968).

The significance of the treatment effect was tested with the help of variance ratio (F value). The value of SE m $\pm$ and least significant difference (LSD) were worked out by the following formula for judging the significance of difference between two treatment means.

$$\text{SE m} \pm = \sqrt{\text{Error mean sum of square (EMSS)} \div \text{Replications (r)}}$$

$$\text{LSD} = \text{SE m} \pm \times \sqrt{2} \times \text{t value at 5\% of level.}$$

Results

CHAPTER IV

EXPERIMENTAL RESULTS

The results obtained during field experimentation have been presented in this chapter along with appropriate tables and illustrations.

4.1 Effect of intercrops (blackgram and mustard) on growth of *Albizia procera*

4.1.1 Height, Collar diameter and Crown diameter

The data growth (height, collar and crown diameter) parameters of *Albizia procera* in tree-crop system as well as pure tree have been presented in Table 4.1.1. The growth performance of *Albizia procera* in tree-crop system did not vary significantly with pure tree during both the years. However, during 2001only crown diameter of the tree was significantly higher in pure tree compared to that tree-crop system. In general, the growth performance of tree was obviously better in those treatments in which trees were growing normally and associated crop (mustard) received irrigation as per their requirement during both the years. But pruning of tree and soil barrier did not show any influence on tree growth after one or two years after plantation. The growth performance of pure tree was better to that tree-crop system during first year ~~and~~ but during second year, the growth of tree in tree-crop system was some time better/similar to that pure tree.

4.2 Effect of tree on growth and yield attributing characters of intercrop (blackgram)

4.2.1 Germinated plants running meter^{-1}

In general, germination of crop in first row from the tree base was less compared to second, third and fourth rows from tree base after a year of tree plantation. However, the influence of tree pruning (up to 70 per cent plant height) on germination of crop was also noticed in which germination was slightly higher (13.30 to 14.83 and 8.83 to 9.67 plants meter^{-1} during 2001 and 2002, respectively) than the tree was allowed to growing normally (10.17 to 13.67 and 4.33 to 6.17 plants meter^{-1}during 2001 and 2002,

Table 4.1.1 Growth performance of *Albizia procera* after one and two year of plantation

Treatment	Height (m)		Collar diameter (cm)		Crown diameter (m)	
	2001	**2002**	**2001**	**2002**	**2001**	**2002**
Tree allow to grow normally + crop	1.26	2.68	3.34	7.16	1.02	3.28
Pruning of tree up to 70% plant height + crop	1.08	2.26	2.92	5.87	0.71	2.65
Tree allow to grow normally + soil barrier + crop	1.24	2.39	3.39	6.36	1.21	2.71
Pruning of tree up to 70% height + soil barrier + crop	1.29	2.24	3.70	5.98	0.75	2.52
Tree allow to grow normally + crop + irrigation as per requirement of crop	1.45	2.43	3.69	6.63	1.26	3.09
Pruning of tree up to 70% plant height + crop + irrigation as per requirement of the crop	1.46	2.63	4.20	6.86	0.79	3.29
Pure tree (control)	1.54	2.78	3.84	7.09	1.42	3.09
LSD(0.05)	NS	NS	NS	NS	0.47	NS

respectively) during both the years (Table 4.2.1). Germination of crop was 5.35 to 21.21, 9.18 to 32.18 and 21.25 to 36.05 per cent less in first row compared to second, third and fourth rows from tree base respectively under tree-crop system with irrespective of treatments. Although during second year (2002), germination of crop was less, but the germination of crop in first row was 20.54 to 50.03, 18.25 to 45.75 and 13.64 to 51.93 per cent less from second, third and fourth rows from tree base respectively. Overall, the germination in pure crop (16.78 plants running meter^{-1}) was 9.03 per cent higher as compared to that tree-crop system (15.39 plants running meter^{-1}) during 2001 (number of germinated plants meter^{-1} in pure crop have been given in Table 4.2.9). Similarly during second year, germination of pure crop (10.25 plants running meter^{-1}) was 9.07 per cent higher as compared to that tree-crop system (9.32 plants running meter^{-1}) irrespective of treatments and different rows from the tree base.

4.2.2 Plant height (cm)

Data on plant height of blackgram (at harvest) have been given in Table 4.2.2, which revealed that plant height in first row from the tree base was less compared to second, third and fourth rows of crop. After one or two years of planting of tree, the effect of tree was only observed up to second row. However this effect was more pronounced during second year. The effect of pruning of tree up to 70 per cent plant height was very much obvious on plant height of the crop, in this treatment height of crop was better (38.92, 33.08, 31.58 cm and 43.38, 35.22, 34.08 cm in first row during 2001 and 2002, respectively) irrespective of irrigation and soil barrier during both the years. The plant height of crop was almost similar in third and fourth rows and in some cases plant height was better in third row and in some cases it was better in fourth row, which indicate that there was no definite trend in growth of crop due to competitiveness of tree on crop in tree-crop system after one or two years of planting (Table 4.1.1).

4.2.3 Branches plant $^{-1}$

The effect of tree on branching in crop (Table 4.2.3) indicated that number of branches plant^{-1} was slightly less (4.00 to 6.33 branches plant^{-1}) in first row of crop from tree base compared to second row (5.17 to 7.33 branches plant^{-1}) irrespective of

Table 4.2 Growth and yield attributing characters of blackgram in *Albizia procera* based agroforestry system

Table 4.2.1 Germinated plants running meter^{-1} at 15 days after sowing

Treatment	2001				2002			
	Number of row from tree base							
	1	2	3	4	1	2	3	4
Tree allow to grow normally + crop	10.17	11.67	13.83	15.33	4.33	6.17	6.83	9.00
Pruning of tree up to 70% plant height + crop	13.30	14.50	16.83	17.83	8.83	12.00	11.33	10.50
Tree allow to grow normally + soil barrier + crop	11.67	12.33	14.50	17.00	6.33	8.50	9.17	7.33
Pruning of tree up to 70% height + soil barrier + crop	14.83	14.83	16.33	18.83	9.67	12.17	11.83	12.67
Tree allow to grow normally + crop + irrigation as per requirement of crop	13.67	16.50	18.33	18.33	6.17	10.50	8.83	7.83
Pruning of tree up to 70% plant height + crop + irrigation as per requirement of the crop	13.00	16.50	19.17	20.33	6.33	12.67	11.67	13.17
LSD(0.05)	2.55	2.23	2.30	1.92	2.04	2.61	2.96	NS

Table 4.2.2 Plant height (cm)

Treatment	2001				2002			
	Number of row from tree base							
	1	2	3	4	1	2	3	4
Tree allow to grow normally + crop	30.33	33.67	37.00	42.33	37.60	40.27	40.27	40.99
Pruning of tree up to 70% plant height + crop	33.08	35.42	36.58	35.33	43.38	42.83	45.94	44.49
Tree allow to grow normally + soil barrier + crop	31.33	34.08	36.67	33.58	41.55	41.27	39.69	39.77
Pruning of tree up to 70% height + soil barrier + crop	31.58	31.17	34.00	38.00	34.08	40.66	40.69	40.44
Tree allow to grow normally + crop + irrigation as per requirement of crop	35.17	34.92	37.92	40.42	33.75	38.77	39.44	41.16
Pruning of tree up to 70% plant height + crop + irrigation as per requirement of the crop	38.92	40.42	39.92	48.50	35.22	35.38	36.72	38.77
LSD(0.05)	5.04	4.44	NS	6.39	NS	NS	NS	NS

Table 4.2.3 Branches $plant^{-1}$

Treatment	2001				2002			
	Number of row from tree base							
	1	2	3	4	1	2	3	4
Tree allow to grow normally + crop	4.00	5.50	5.00	6.00	3.58	4.52	4.89	5.13
Pruning of tree up to 70% plant height + crop	4.50	5.17	5.83	5.50	5.02	6.11	5.63	5.25
Tree allow to grow normally + soil barrier + crop	5.33	5.17	4.50	5.00	5.08	5.88	5.55	5.94
Pruning of tree up to 70% height + soil barrier + crop	5.67	6.50	6.17	6.83	6.17	6.50	6.50	7.33
Tree allow to grow normally + crop + irrigation as per requirement of crop	4.83	5.67	5.83	6.67	4.52	5.33	5.38	5.02
Pruning of tree up to 70% plant height + crop + irrigation as per requirement of the crop	6.33	7.33	6.67	7.50	5.83	6.92	6.83	6.83
LSD(0.05)	1.01	1.39	1.19	1.25	NS	NS	NS	1.35

treatments. Among different treatments, pruning of tree up to 70 per cent plant height (irrespective to soil barrier, irrigation as per requirement the crop) had better branching (4.50, 5.67 and 6.33 branches plant^{-1} during 2001 and 5.02, 6.17 and 5.83 branches plant^{-1} during 2002 in first row from tree base) compared to other treatments. The effect of tree on branching of crop was seen only up to first row and very little effect was noticed on second row during first and second year. Soil barrier had significant effect on branching of an associated crop in tree-crop system after a year of planting as compared to without soil barrier and either tree was growing normally or pruned up to 70 per cent plant height (Table 4.2.3). However the number of branching plant^{-1} was also higher with soil barrier but the differences were not significant.

4.2.4 Pods plant $^{-1}$

In general number of pod in first row from the tree base was 4.06 to 9.44 per cent less as compared to second row of crop from tree base during 2001 and this different was 1.34 to 10.49 per cent during 2002 (Table 4.2.4). The effect of treatments was also significant on pod formation of crop in first to fourth rows during 2001. But the differences in pod number were only significant in first and fourth row during 2002. Among all the treatments, pruning of tree up to 70 per cent plant height + irrigation as per requirement of crop and tree allowing to grow normally + irrigation as per requirement of crop were significantly better to contribute more pods plant^{-1} than other treatments but pruning of tree up to 70 per cent plant height + irrigation as per requirement of crop was overall significantly superior than rest of the treatments during both the years. Number of pods per plant under tree-crop system was less as compared to that pure cropping irrespective of treatments and different rows from tree base. In management practices, tree pruning favoured more towards pod formation in crop during both the years but at this stage soil barrier had little influence on growth and yield attributes of crop. The contribution of irrigation was very much obvious on pod formation during 2001, when rain was terminated earlier than normal (Table 4.2.4).

Table 4.2.4 Pods $plant^{-1}$

Treatment	2001				2002			
	Number of row from tree base							
	1	2	3	4	1	2	3	4
Tree allow to grow normally + crop	19.83	20.67	26.67	30.17	18.36	18.83	20.81	20.88
Pruning of tree up to 70% plant height + crop	19.17	21.17	24.83	29.17	23.00	23.86	31.44	32.00
Tree allow to grow normally + soil barrier + crop	23.83	24.83	31.33	33.17	22.92	25.61	27.40	29.80
Pruning of tree up to 70% height + soil barrier + crop	28.17	30.17	36.17	38.67	31.57	32.00	40.43	43.50
Tree allow to grow normally + crop + irrigation as per requirement of crop	28.50	31.00	31.67	34.50	24.44	25.69	27.22	33.00
Pruning of tree up to 70% plant height + crop + irrigation as per requirement of the crop	34.83	36.67	43.17	48.67	27.74	30.08	32.85	35.50
LSD(0.05)	3.45	4.57	5.26	7.13	6.55	NS	NS	8.03

4.2.5 Seeds pod^{-1}

Tree did not affect the seed formation in crop either near by the tree base (first row from tree base) or away from the tree base (second, third and fourth rows from tree base) after one or two years of planting. Seeds pod^{-1} ranged from 6.53 to 6.88 and 6.43 to 6.90 in first and second row respectively during 2001 irrespective of treatments and these values were less (6.22 to 6.44 and 5.69 to 6.58 in first and second row, respectively) during 2002. Among different treatments seeds pod^{-1} were not varied significantly during both the years (Table 4.2.5). In tree-crop system on an average 6.70 and 6.22 seeds pod^{-1}were observed during 2001 and 2002, respectively irrespective of treatments and different rows from tree base, which were almost similar to that pure crop (6.85 and 6.71 seeds pod^{-1} during 2001 and 2002, respectively).

4.2.6 Grain yield (g) running meter^{-1}

The effect on trees on grain yield of crop in tree-crop system showed that during first year the grain yield running meter^{-1}in first row was 2.47 to 9.32 per cent less than the yield obtained in second row. Like wise the yield of second row was 5.06 to 11.05 per cent less than the yield of third row from the tree base irrespective of treatments (Table 4.2.6). However the treatments effect was not significant during first year. The grain yield obtained in fourth row was slightly higher than second row. During second year the effect of trees on grain yield in first row was more pronounced and it was 2.42 to 22.77 per cent less than the yield obtained in second row. Similarly, the grain yield in second row was 1.65 to 7.46 per cent less than the grain yield of third row irrespective of treatments. The significant effect of treatments was observed in first, third and fourth rows from the tree base during 2002.

After comparing the effect of different management practices like pruning, soil barrier and irrigation as per requirement of the crop Vs tree allowed to grow normally, no soil barrier, and moisture stress situation during 2001. The grain yield of crop in first row was 3.68 per cent higher in pruning of tree than tree allowed to grow normally in moisture stress situation. In other hand, under required irrigation, the yield of grain in first row was 3.24 per cent higher in pruning of tree than tree allowed to grow normally

Table 4.2.5 Seeds pod^{-1}

Treatment	2001				2002			
	Number of row from tree base							
	1	2	3	4	1	2	3	4
Tree allow to grow normally + crop	6.78	6.70	6.88	6.75	6.39	5.69	5.88	6.22
Pruning of tree up to 70% plant height + crop	6.77	6.90	6.44	6.77	6.22	6.13	6.24	6.61
Tree allow to grow normally + soil barrier + crop	6.53	6.43	6.47	7.09	6.39	6.33	6.55	6.13
Pruning of tree up to 70% height + soil barrier + crop	6.66	6.60	6.67	6.50	6.44	6.58	5.83	6.44
Tree allow to grow normally + crop + irrigation as per requirement of crop	6.76	6.87	6.53	6.28	5.86	6.38	6.14	6.47
Pruning of tree up to 70% plant height + crop + irrigation as per requirement of the crop	6.88	6.63	6.93	6.98	6.00	6.44	6.41	6.92
LSD(0.05)	NS	NS	NS	0.39	NS	NS	NS	NS

Table 4.2.6 Grain yield (g) running meter^{-1}

Treatment	2001				2002			
	Number of row from tree base							
	1	2	3	4	1	2	3	4
Tree allow to grow normally + crop	17.50	19.30	20.33	21.50	16.46	18.84	19.90	25.34
Pruning of tree up to 70% plant height + crop	18.17	19.20	21.33	25.17	31.74	32.53	33.44	33.83
Tree allow to grow normally + soil barrier + crop	18.50	20.80	22.83	24.00	25.60	28.85	30.09	31.32
Pruning of tree up to 70% height + soil barrier + crop	18.83	19.50	20.67	23.67	34.95	42.77	43.49	45.04
Tree allow to grow normally + crop + irrigation as per requirement of crop	19.67	20.17	20.83	29.17	22.75	28.12	30.39	31.21
Pruning of tree up to 70% plant height + crop + irrigation as per requirement of the crop	20.33	21.33	23.83	26.50	27.69	34.95	36.54	37.27
LSD(0.05)	NS	NS	NS	NS	6.27	NS	11.05	7.46

during first year. In another situation, when the moisture and nutrients competition has been separated by soil barrier in between tree and crop, the grain yield in first was 4.44 per cent higher than without barrier irrespective of pruning and naturally growing trees. Lastly, if we compare the moisture stress and irrigation as per requirement of crop, the grain yield was 10.82 per cent higher in first row from tree base in irrigation as per requirement of crop compared to moisture stress during first year. Similar results were also found during the second year but the effect of moisture was nullified due to natural rain received during pod formation and maturity. Overall the grain yield running meter^{-1} in case of pure crop was 3.07 and 3.90 per cent higher than the yield received in tree-crop system irrespective of treatments during 2001 and 2002, respectively.

4.2.7 Test weight (g)

Test weight of seed in different treatments varied from 32.00 to 35.67 g in first row, 32.33 to 35.67 g in second row during 2001. Similarly it was varied from 41.73 to 43.28 g in first row and 41.98 to 44.67 g in second row during 2002 (Table 4.2.7). Test weight of seed was better in pruning of tree up to 70 per cent plant height irrespective of soil barrier and irrigation as per requirement of the crop. The effect of treatments was significant in first row and fourth row only during 2001 and in second year the differences were not significant. The overall test weight of crop in tree-crop system was almost similar to that pure crop (Table 4.2.9) during both the years.

4.2.8 Grain yield (q ha^{-1})

The grain yield of crop during 2001 was higher than 2002. Among different treatments, the grain yield was maximum in pruning of tree up to 70 per cent plant height + irrigation given to the crop as per their requirement during both the years (Table 4.2.8). In over all comparison, the pure crop yield was 6.58 per cent higher during 2001 and 20.71 per cent higher during 2002 compared to that tree-crop system. If the data on grain yield of two years in tree-crop system are compared in different way, like tree allowing to grow normally Vs pruning of tree up to 70 per cent plant height, tree allowing to grow normally + soil barrier Vs pruning of trees up to 70 per cent plant height + soil barrier, tree allowing to grow normally + irrigation as per requirement of crop Vs pruning of tree

Table 4.2.7 Test weight (g)

Treatment	2001				2002			
	Number of row from tree base							
	1	2	3	4	1	2	3	4
Tree allow to grow normally + crop	32.00	32.33	35.33	35.67	41.81	43.07	42.56	42.82
Pruning of tree up to 70% plant height + crop	32.33	32.67	33.67	34.60	42.81	43.42	46.26	47.93
Tree allow to grow normally + soil barrier + crop	33.14	34.33	34.67	35.33	41.73	41.98	42.34	43.27
Pruning of tree up to 70% height + soil barrier + crop	34.23	34.70	35.67	36.00	42.47	45.14	45.20	45.06
Tree allow to grow normally + crop + irrigation as per requirement of crop	34.00	34.67	34.33	35.33	42.19	44.07	43.95	44.10
Pruning of tree up to 70% plant height + crop + irrigation as per requirement of the crop	35.67	35.67	35.80	37.00	43.28	44.67	44.70	44.85
LSD(0.05)	1.71	NS	NS	1.32	NS	NS	NS	NS

Table 4.2.8 Grain yield (q ha^{-1})

Treatment	Grain yield	
	2001	**2002**
Tree allow to grow normally + crop	7.00	5.15
Pruning of tree up to 70% plant height + crop	7.33	7.55
Tree allow to grow normally + soil barrier + crop	7.17	6.10
Pruning of tree up to 70% height + soil barrier + crop	7.40	7.90
Tree allow to grow normally + crop + irrigation as per requirement of crop	7.63	6.55
Pruning of tree up to 70% plant height + crop + irrigation as per requirement of the crop	7.80	8.10
LSD(0.05)	NS	NS

Table 4.2.9 Growth performance, yield and yield attributing characters of pure crop of blackgram

Characters	2001	2002*
Germinated plants running meter^{-1} at 15 DAS	16.78 (16.80)	10.25
Plant height (cm)	43.10 (48.72)	44.96
Branches plant^{-1}	7.21 (8.00)	6.36
Pods plant^{-1}	44.70 (48.90)	27.19
Seeds pod^{-1}	6.85 (7.10)	6.71
Grain yield (g) running meter $^{-1}$	22.10 (30.06)	32.23
Test weight (g)	36.16 (37.02)	43.20
Grin yield (q ha^{-1})	7.90(8.30)	8.69

Note: Figure in parenthesis are the value of growth, yield and yield attributing characters, in which one irrigation was give to the crop at pod formation stage.

* During 2002, no moisture deficit was observed, because during September, the crop received 116.5 mm rain.

up to 70 per cent plant height + irrigation as per requirement of the crop and tree-crop system Vs pure crop. The results revealed that the grain yield under pruning of trees up to 70 per cent plant height was 4.50 per cent higher than tree allow to growing normally, 3.10 per cent higher in pruning of trees up to 70 per cent plant height + soil barrier than tree allowing to grow normally + soil barrier and the grain yield was 2.17 per cent higher in case of pruning of trees up to 70 per cent plant height + irrigation as per requirement of crop than tree allow to growing normally + irrigation as per requirement of crop. The effect of pruning and soil barrier was more pronounced on grain yield under moisture stress situation as compared to no moisture stress during 2001(Table 4.2.8). The similar results were also obtained during second year but differences in yield between the treatments were up to 24.30 per cent (Table 4.2.8), which was higher than first year. The effect of moisture on grain yield was less during second year because the crop received rain during pod formation and maturity.

4.3 Effect of tree on growth and yield attributing characters of intercrop (mustard)

4.3.1 Germinated plants running meter^{-1}

Data on germinated plant running meter^{-1}in different treatments and different rows from tree base have been given in Table 4.3.1, which revealed that plant population did not vary significantly within the treatments during first year (2000-01). The similar results were also obtained during second year in case of first and second rows from tree base. However in third and fourth rows the differences were significant. The plant population near by the tree base (first row) indicates that after four months of plantation, tree (planted during July, 2000) did not exert any adverse effect on germination of crop either in first or in second row and so on. During second year also, the effect of tree was not obvious on the germination of crop.

4.3.2 Plant height (cm)

Plant height of mustard was recorded before harvesting of crop and data presented in Table 4.3.2. It clearly showed that the maximum (average plant height 201.17, 193.33, 216.00, 219.67 cm in first, second, third and fourth rows from tree base, respectively)

Table 4.3 Growth and yield attributing characters of mustard in *Albizia procera* based agroforestry system

Table 4.3.1 Germinated plants running meter^{-1} at 15 days after sowing

Treatment	2000-01				2001-02			
	Number of row from tree base							
	1	2	3	4	1	2	3	4
Tree allow to grow normally + crop	8.00	8.33	8.33	8.83	7.33	7.00	7.67	7.83
Pruning of tree up to 70% plant height + crop	6.50	7.33	7.17	8.00	7.83	7.17	7.83	8.67
Tree allow to grow normally + soil barrier + crop	7.83	7.00	8.00	6.67	7.17	7.17	8.50	8.50
Pruning of tree up to 70% height + soil barrier + crop	7.67	8.17	8.00	7.95	8.50	7.83	9.00	8.67
Tree allow to grow normally + crop + irrigation as per requirement of crop	9.67	6.83	8.33	7.50	7.33	7.83	9.83	8.67
Pruning of tree up to 70% plant height + crop + irrigation as per requirement of the crop	8.33	8.83	8.83	7.17	7.83	8.17	9.17	9.17
LSD(0.05)	NS	NS	NS	NS	NS	NS	1.39	0.72

Table 4.3.2 Plant height (cm)

Treatment	2000-01				2001-02			
	Number of row from tree base							
	1	2	3	4	1	2	3	4
Tree allow to grow normally + crop	180.50	182.50	198.33	191.00	190.00	196.83	193.17	198.67
Pruning of tree up to 70% plant height + crop	191.71	211.00	205.00	209.00	191.33	197.83	200.50	201.83
Tree allow to grow normally + soil barrier + crop	191.50	192.33	194.17	182.33	184.67	188.50	184.50	194.83
Pruning of tree up to 70% height + soil barrier + crop	192.00	193.00	195.33	194.00	196.83	190.33	197.00	211.83
Tree allow to grow normally + crop + irrigation as per requirement of crop	198.17	211.50	211.67	216.00	192.83	196.33	204.00	211.00
Pruning of tree up to 70% plant height + crop + irrigation as per requirement of the crop	201.17	193.33	216.00	219.67	201.67	207.55	208.83	211.83
LSD(0.05)	NS	NS	NS	NS	NS	NS	NS	NS

plant height was recorded in pruning of tree up to 70 per cent plant height + irrigation as per requirement of crop followed by tree allowing to grow normally + irrigation as per requirement of the crop. In rest of treatments, in which crop received only one irrigation at flowering stage, plant height of crop was better in pruning of tree up to 70 per cent plant height + soil barrier as compared to tree allowing to grow normally with and without soil barrier during 2000-01. Similar results were also obtained during 2001-02 in all treatments as well as in different rows from tree base. In general, the plant height of crop was less in first row in most of the treatments during both the years.

4.3.3 Branches plant $^{-1}$

The number of branches plant^{-1} ranged from 15.83 to 26.77 in different treatments irrespective of rows from tree base during 2000-01. Similarly during 2Q01-02, the branches plant^{-1} varied from 17.33 to 33.83 in different treatments (Table 4.3.3). In all the treatments branching in crop under first row was less as compared to second, third and fourth rows from tree base during both the years. The number of branches increased with increasing distances from tree base. The competitive effect of tree during second year was more obvious on first that affected the branching of crop but this effect was not seen in third and fourth rows from tree base. Among different treatments, pruning of tree up to 70 per cent plant height + irrigation given to the crop as per their requirement recorded maximum (18.00, 22.67, 26.77 and 20.67 branches plant^{-1} during 2000-01 and 22.83, 25.83, 29.17, 33.83 branches plant^{-1} during 2001-02 in first to fourth rows respectively) branches during both the years followed by tree allowed to grow normally + irrigation as per requirement of the crop. If a comparison is made in between pruning with or without soil barrier and tree allowed to grow normally with or without soil barrier. It indicated that in moisture stress situation (only one irrigation given to the crop at flowering), number of branches were higher in pruning of tree up to 70 per cent plant height compared to tree allowing to grow normally. Similarly, pruning of tree up to 70 per cent plant height + soil barrier had higher branching in crop compared to tree allowing to grow normally + soil barrier during both the years. In overall comparison of tree-crop system Vs pure crop under moisture stress (one irrigation given at flowering stage), number of branches plant^{-1} in pure crop were 19.23 and 26.42 in 2000-01 and

Table 4.3.3 Branches plant^{-1}

Treatment	2000-01				2001-02			
	Number of row from tree base							
	1	2	3	4	1	2	3	4
Tree allow to grow normally + crop	15.83	17.67	16.67	16.17	17.83	21.17	22.50	23.17
Pruning of tree up to 70% plant height + crop	17.00	18.33	18.50	19.00	19.83	22.17	24.33	24.83
Tree allow to grow normally + soil barrier + crop	17.67	18.67	18.17	17.00	17.33	20.50	21.33	21.33
Pruning of tree up to 70% height + soil barrier + crop	16.00	17.17	18.83	18.83	19.83	25.27	26.33	26.67
Tree allow to grow normally + crop + irrigation as per requirement of crop	17.00	18.27	18.33	19.17	21.50	25.67	30.33	31.17
Pruning of tree up to 70% plant height + crop + irrigation as per requirement of the crop	18.00	22.67	26.77	20.67	22.83	25.83	29.17	33.83
LSD(0.05)	NS	NS	NS	NS	NS	NS	NS	6.18

2001-02 respectively, which were almost similar to intercrop irrespective of treatments. Similarly, in case of no moisture stress situation, where crop has received irrigation as per requirement, number of branches in pure crop (25.08 and 32.24 branches plant^{-1} in 2000-01 and 2001-02 respectively) was apparently equal to intercrop in tree-crop system (Table 4.3.9).

4.3.4 Siliquae plant^{-1}

The results of this character were similar to results obtained in case of number of branches plant^{-1}. However, tree allowed to grow normally + irrigation as per requirement of crop and pruning of tree up to 70 per cent plant height + irrigation as per requirement of the crop had higher siliquae plant^{-1} as compared to rest of the treatments during both the years (Table 4.3.4) but the difference were not significant. The values of this character were higher during 2001-02 compared to 2000-01. If a comparison is made in between two sets of treatment, crop received only one irrigation Vs crop received irrigation as per requirement of crop. It indicated that due to irrigation siliquae plant^{-1} were increased either in pruning or tree allowed to grow normally (Table 4.3.4) during both the years. In overall comparison of tree-crop system with pure crop, siliquae plant^{-1} was higher in pure crop compared to that intercrop.

4.3.5 Seeds siliqua^{-1}

Seeds siliqua^{-1} varied from 11.46 to 15.25 and 13.28 to 15.30 in first row during 2000-01 and 2001-02 respectively. These values were more or less equal to second row during both the years irrespective of treatments. The variation in seed siliqua^{-1} was only up to 1.03 per cent in between first and second rows during 2000-01 and this variation was 2.27 per cent during 2001-02 irrespective of treatments. Among different treatments, the seeds siliqua^{-1} was maximum (14.75 to 15.13 and 15.30 to 17.10 seeds siliqua^{-1} during 2000-01 and 2001-02, respectively) in pruning of tree up to 70 per cent plant height + irrigation as per requirement of the crop followed by tree allow to growing normally + irrigation as per requirement of crop (Table 4.3.5). But the differences were not significant during both the years. After an analysis of data received in tree allow to growing normally Vs pruning of tree up to 70 per cent plant height, the effect of pruning

Table 4.3.4 Siliquae plant^{-1}

Treatment	2000-01				2001-02			
	Number of row from tree base							
	1	2	3	4	1	2	3	4
Tree allow to grow normally + crop	278.50	328.67	263.33	267.83	299.88	313.40	347.25	355.21
Pruning of tree up to 70% plant height + crop	286.33	343.17	279.17	294.00	388.38	388.72	408.02	406.04
Tree allow to grow normally + soil barrier + crop	234.00	360.00	279.83	304.83	343.89	350.83	377.50	381.47
Pruning of tree up to 70% height + soil barrier + crop	281.67	335.50	290.50	262.17	422.20	425.21	439.10	488.33
Tree allow to grow normally + crop + irrigation as per requirement of crop	306.33	357.17	349.50	305.83	432.57	440.50	450.20	472.13
Pruning of tree up to 70% plant height + crop + irrigation as per requirement of the crop	304.67	373.17	348.33	307.17	439.87	477.13	503.33	538.23
LSD(0.05)	NS	NS	NS	NS	44.38	36.83	43.67	71.27

Table 4.3.5 Seeds siliqua^{-1}

Treatment	2000-01				2001-02			
	Number of row from tree base							
	1	2	3	4	1	2	3	4
Tree allow to grow normally + crop	14.37	13.58	14.70	13.66	13.33	13.33	14.67	14.67
Pruning of tree up to 70% plant height + crop	14.33	13.37	14.25	13.37	14.00	14.00	15.38	15.20
Tree allow to grow normally + soil barrier + crop	13.56	14.04	13.96	14.16	13.28	13.87	14.20	14.65
Pruning of tree up to 70% height + soil barrier + crop	11.46	14.50	12.70	14.16	13.97	14.46	14.67	15.94
Tree allow to grow normally + crop + irrigation as per requirement of crop	15.00	14.58	15.12	14.29	14.24	15.05	15.83	16.43
Pruning of tree up to 70% plant height + crop + irrigation as per requirement of the crop	15.25	14.75	15.47	15.13	15.30	15.37	16.30	17.10
LSD(0.05)	NS	NS	NS	NS	NS	NS	NS	NS

on seeds siliqua^{-1} was obvious during second year only. Similarly in case of tree allow to growing normally + soil barrier Vs pruning of tree up to 70 per cent plant height + soil barrier, pruning of tree up to 70 per cent plant height + soil barrier had higher seeds siliqua^{-1} in all the rows during second year. In overall comparison of tree-crop system with pure crop, seeds siliqua^{-1} in tree-crop system (14.29 to 15.47 and 14.24 to 17.10 seeds siliqua^{-1} during 2000-01 and 2001-02, respectively) was less to that pure crop (15.72 and 17.39 seeds siliqua^{-1} during 2000-01 and 2001-02, respectively) either crop received irrigation as per requirement or only one irrigation at flowering stage.

4.3.6 Grain yield (g) running meter^{-1}

Data on grain yield running meter^{-1} have been given in Table 4.3.6, which revealed that during 2000-01, the grain yield in first, second, third and fourth rows was more or less equal to each other. But during second year, the grain yield running meter^{-1} in first row was less than second, third and fourth rows in all the treatments. The effects of treatment on grain yield running meter^{-1} were not significant during 2000-01. But the differences in grain yield due to treatments were significant during 2001-02.

The effect of management practices like pruning, irrigation as per requirement of crop and soil barrier on grain yield was not significant during 2000-01. But the yield of crop obtained in tree allowed to grow normally was 6.93 per cent less as compared to pruning of tree up to70 per cent plant height in first row of crop. Similarly the grain yield running meter^{-1} was about 7.16 per cent less in tree allowed to grow normally as compared to pruning of tree up to 70 per cent plant height + soil barrier in first row. Similar results were also obtained in rest of the rows of crops during 2001-02. The influence of irrigation was more obvious on grain yield running meter^{-1} during both the years and due to irrigation as per requirement of crop the grain yield was 18.53 and 16.16 per cent higher during 2000-01 and 2001-02, respectively than the crop received one irrigation at flowering.

In over all comparison of tree-crop system (Table 4.3.6) with pure cropping (Table 4.3.9) the results revealed that in tree-crop system the grain yield of crop was about 39.13 g meter^{-1} and 60.69 g meter^{-1} during 2000-01 and 2001-02 respectively

Table 4.3.6 Grain yield (g) running meter^{-1}

Treatment	2000-01				2001-02			
	Number of row from tree base							
	1	2	3	4	1	2	3	4
Tree allow to grow normally + crop	36.23	37.27	38.11	40.23	49.37	51.57	54.66	56.89
Pruning of tree up to 70% plant height + crop	38.93	39.61	40.43	44.23	53.31	57.12	58.69	59.68
Tree allow to grow normally + soil barrier + crop	39.00	35.01	38.21	38.16	50.69	52.88	54.74	57.13
Pruning of tree up to 70% height + soil barrier + crop	41.70	37.88	39.51	41.72	53.85	57.37	59.40	61.88
Tree allow to grow normally + crop + irrigation as per requirement of crop	45.07	44.42	45.36	52.53	65.52	67.95	68.10	68.45
Pruning of tree up to 70% plant height + crop + irrigation as per requirement of the crop	47.29	47.03	48.33	59.69	70.50	73.20	74.75	75.90
LSD(0.05)	NS	NS	NS	NS	6.03	4.41	6.50	6.48

irrespective of treatments and different rows from tree base under one irrigation of crop at flowering stage (Table 4.3.6). In same situation, the pure crop yield was 46.71 and 63.14 g meter^{-1} during 2000-01 and 2001-02, respectively. Similarly in case of irrigation given to the crop as per their requirement, the grain yield was about 48.71 and 70.54 g meter^{-1} in tree-crop system during 2000-01 and 2001-02, respectively, irrespective of treatments and rows from tree base. The yield of pure crop under same situation was 60.16 and 79.70 g meter^{-1} during 2000-01 and 2001-02, respectively.

4.3.7 Test weight (g)

The test weight of seeds did not vary significantly among different treatments during both the years (Table 4.3.7). However, higher test weight was recorded in tree allowed to grow normally + irrigation as per requirement of crop and pruning of trees up to 70 per cent plant height compared to other treatments during both the years. During first year (2000-01) the test weight of seed in first row under different treatments varied from 5.30 to 6.83 g but these values were similar to second, third and fourth rows from tree base. But during second year (2001-02), the test weight of seed was less in first row under all the treatments as compared to second, third and fourth rows from tree base.

In overall comparison of tree-crop system to that pure cropping, the test weight was higher in pure crop compared to intercrop with tree either crop received one irrigation or as per their requirement.

4.3.8 Grain yield (q ha^{-1})

The grain yield obtained under different treatments during first year was less as compared to second year (Table 4.3.8). The grain yield of crop did not vary significantly during first year but the differences in yield under different treatments were significant during second year.

After comparing the yield of crop under different group of treatments, it clearly showed that crop yield under tree allowed to grow normally was 14.57 and 6.77 per cent less during 2000-01 and 2001-02, respectively compared to pruning of tree up to 70 per cent plant height. The crop yield under tree allowed to grow normally + soil barrier was

Table 4.3.7 Test weight (g)

Treatment	2000-01				2001-02			
	Number of row from tree base							
	1	2	3	4	1	2	3	4
Tree allow to grow normally + crop	5.30	5.32	5.58	5.45	4.56	4.67	4.87	4.98
Pruning of tree up to 70% plant height + crop	5.73	5.46	5.70	6.38	4.95	5.13	5.09	5.08
Tree allow to grow normally + soil barrier + crop	6.08	5.23	5.03	5.17	4.61	4.65	5.07	5.06
Pruning of tree up to 70% height + soil barrier + crop	6.45	5.60	5.25	5.93	4.99	5.00	5.35	5.54
Tree allow to grow normally + crop + irrigation as per requirement of crop	6.43	6.24	5.97	6.02	4.67	5.01	5.33	5.47
Pruning of tree up to 70% plant height + crop + irrigation as per requirement of the crop	6.83	6.70	5.97	6.18	4.86	5.01	5.44	5.69
LSD(0.05)	NS	NS	NS	NS	NS	NS	NS	NS

Table 4.3.8 Grain yield (q ha^{-1})

Treatment	Grain yield	
	2000-01	**2001-02**
Tree allow to grow normally + crop	8.85	11.14
Pruning of tree up to 70% plant height + crop	10.36	11.95
Tree allow to grow normally + soil barrier + crop	9.64	13.72
Pruning of tree up to 70% height + soil barrier + crop	10.61	14.59
Tree allow to grow normally + crop + irrigation as per requirement of crop	11.17	16.28
Pruning of tree up to 70% plant height + crop + irrigation as per requirement of the crop	11.28	16.93
LSD(0.05)	NS	3.89

Table 4.3.9 Growth performance, yield and yield attributing characters of pure crop of mustard

Characters	Irrigation as per requirement of crop		One irrigation at flowering	
	2000-01	**2001-02**	**2000-01**	**2001-02**
Germinated plants running meter^{-1} at 15 DAS	7.91	8.33	6.57	7.24
Plant height (cm)	184.41	200.33	176.32	184.12
Branches plant^{-1}	25.08	32.24	19.23	26.42
Siliquae plant^{-1}	398.33	539.25	458.20	489.02
Seeds siliqua^{-1}	15.72	17.39	14.01	14.57
Grain yield (g) running meter^{-1}	60.16	79.70	46.71	63.14
Test weight (g)	6.55	5.57	5.75	5.29
Grain yield (q ha^{-1})	12.11	17.23	10.89	15.29

9.14 and 5.96 per cent less during 2000-01 and 2001-02 respectively compared to pruning of tree up to 70 per cent plant height + soil barrier. Similarly, crop yield obtained under tree allowing to grow normally + irrigation as per requirement of crop was 0.97 and 3.83 per cent less during 2000-01 and 2001-02, respectively compared to pruning of trees up to 70 per cent plant height + irrigation as per requirement of crop.

In overall comparison of crop yield received under tree-crop system and pure cropping, the grain yield under pure crop was 9.45 and 15.95 per cent higher compared to tree-crop system during 2000-01 and 2001-02, respectively in different treatments either crop received only one-irrigation or crop received irrigation as per their requirement.

4.4 Weed density and dry matter accumulation

4.4.1 Weed density and dry matter accumulation under blackgram

The crop was infested with *Cyprus iria*, *Digera arvensis*, *Cynodon dactylon*, *Phylanthus niruri*, *Echinocloa crusgalli* and *Commelina benghalensis*. The weed density and dry matter of weeds m^{-2} were recorded at 30 days after sowing and at harvest of crop. The data revealed that the values of weed count and dry weight were varied significantly among the different treatments (Table 4.4.1 and 4.4.2) during both the years but during second year dry weight of weeds g m^{-2} at harvest was not significant. The weeds dry weight and their count were significantly higher in those treatments, in which the tree was allowed to grow normally irrespective of soil barrier or irrigation as per requirement of crop. In case of pure crop the values of weed count and dry weight m^{-2} were almost similar to that intercropped with trees.

4.4.2 Weed density and dry matter accumulation under mustard

In rabi crop, the field was infested by *Chenopodium album*, *Fumaria parviflora*, *Anagallis arvensis*, *Melilotus species*, *Vicia sativa*, *Cyprus rotundus* and *Cynodon dactylon*. Infestation of weeds during first year was more as compared to second year (Table 4.4.3), however the weeds were almost similar in tree-crop system and in pure crop during both the years at 30 days after sowing. Weeds m^{-2} at harvest was higher (17.78 and 10.03 weeds m^{-2} during 2000-01 and 2001-02, respectively) in tree allowed to

Table 4.4 Weed count and weeds dry weight in blackgram–mustard crop sequence under *Albizia procera* based agroforestry system

Table 4.4.1 Weed count of blackgram (m^{-2})

Treatment	Weeds count			
	30 days after sowing		At harvest	
	2001	**2002**	**2001**	**2002**
Tree allow to grow normally + crop	7.35(53.66)	7.77(60.00)	6.47(41.66)	5.59(31.00)
Pruning of tree up to 70% plant height + crop	6.61(43.33)	6.51(42.33)	5.31(28.00)	4.38(19.00)
Tree allow to grow normally + soil barrier + crop	7.39(54.33)	7.91(62.33)	6.12(37.00)	5.23(27.00)
Pruning of tree up to 70% height + soil barrier + crop	6.69(45.00)	5.94(35.00)	5.46(29.33)	4.25(18.00)
Tree allow to grow normally + crop + irrigation as per requirement of crop	6.50(42.00)	7.85(61.67)	5.53(30.66)	5.30(28.00)
Pruning of tree up to 70% plant height + crop + irrigation as per requirement of the crop	5.38(28.66)	6.91(47.67)	4.37(18.66)	4.83(23.00)
Pure crop (control)	6.14(37.66)	5.20(26.67)	4.44(19.33)	3.84(14.33)
LSD(0.05)	1.17	0.77	0.96	1.07

Table 4.4.2 Weeds dry weight of blackgram (g m^{-2})

Treatment	Weeds dry weight			
	30 days after sowing		At harvest	
	2001	**2002**	**2001**	**2002**
Tree allow to grow normally + crop	5.45(29.33)	5.36(28.33)	4.48(22.16)	4.47(19.69)
Pruning of tree up to 70% plant height + crop	4.97(24.36)	4.73(22.01)	4.12(16.53)	4.73(22.28)
Tree allow to grow normally + soil barrier + crop	6.28(39.30)	5.49(29.70)	4.75(22.23)	4.68(21.70)
Pruning of tree up to 70% height + soil barrier + crop	5.46(29.43)	4.30(18.03)	4.42(19.13)	3.69(13.42)
Tree allow to grow normally + crop + irrigation as per requirement of crop	5.10(25.63)	6.01(35.72)	4.34(18.43)	4.64(21.10)
Pruning of tree up to 70% plant height + crop + irrigation as per requirement of the crop	4.46(19.46)	5.06(25.22)	3.61(12.60)	4.33(18.33)
Pure crop (control)	4.73(22.10)	4.23(17.45)	3.38(10.96)	3.91(15.03)
LSD(0.05)	0.74	0.40	0.55	NS

Table 4.4.3 Weed count of mustard (m^{-2})

Treatment	Weeds count			
	30 days after sowing		At harvest	
	2000-01	**2001-02**	**2000-01**	**2001-02**
Tree allow to grow normally + crop	13.46(181.33)	5.68(32.00)	14.89(288.00)	9.91(98.00)
Pruning of tree up to 70% plant height + crop	13.03(177.66)	6.00(35.33)	16.84(286.33)	9.63(92.33)
Tree allow to grow normally + soil barrier + crop	12.37(163.66)	6.03(36.33)	13.66(190.33)	8.35(70.00)
Pruning of tree up to 70% height + soil barrier + crop	13.49(187.33)	5.70(32.33)	10.81(116.66)	7.47(55.66)
Tree allow to grow normally + crop + irrigation as per requirement of crop	12.04(151.33)	6.09(36.66)	17.78(340.66)	10.03(100.33)
Pruning of tree up to 70% plant height + crop + irrigation as per requirement of the crop	12.87(166.00)	5.39(28.66)	17.70(314.33)	10.25(105.00)
Pure crop (control)	12.22(153.66)	5.81(33.33)	11.95(143.33)	9.01(81.00)
LSD(0.05)	NS	NS	4.74	1.18

Table 4.4.4 Weeds dry weight of mustard (g m^{-2})

Treatment	Weeds dry weight			
	30 days after sowing		At harvest	
	2000-01	**2001-02**	**2000-01**	**2001-02**
Tree allow to grow normally + crop	3.77(13.88)	2.63(6.50)	7.29(52.72)	5.88(34.16)
Pruning of tree up to 70% plant height + crop	3.70(13.62)	2.60(6.33)	7.87(62.42)	5.42(28.96)
Tree allow to grow normally + soil barrier + crop	4.70(21.71)	2.48(5.71)	7.50(55.74)	4.76(22.30)
Pruning of tree up to 70% height + soil barrier + crop	3.97(16.04)	2.42(5.45)	6.23(38.40)	4.58(20.62)
Tree allow to grow normally + crop + irrigation as per requirement of crop	5.31(28.82)	2.76(7.15)	7.74(59.78)	6.47(41.56)
Pruning of tree up to 70% plant height + crop + irrigation as per requirement of the crop	4.16(17.26)	2.57(6.13)	6.84(46.61)	6.17(37.65)
Pure crop (control)	3.56(12.35)	2.66(6.63)	7.79(60.62)	5.96(35.16)
LSD(0.05)	NS	NS	0.95	0.53

Note: Figure in parentheses are original value
Transformed by $\sqrt{X + 0.5}$

grow normally + irrigation as requirement of crop than in pruning of tree up to 70 per cent plant height + irrigation as per requirement of the crop (17.70 and 10.25 weeds m^{-2} during 2000-01 and 2001-02, respectively). The similar results were also obtained in case of dry weight of weeds g m^{-2} at 30 days after sowing and at harvest (Table 4.4.3 and 4.4.4).

4.5 Light interception

4.5.1 Light intercepted by an intercrop (blackgram) in tree-crop system

Light interception at different distances from tree base was recorded in only two treatments (tree allow to growing normally and pruning of tree up to 70 per cent plant height) and data have been presented in Table 4.5.1 which revealed that the light interception at 0.5, 1.0, 2.0, 3.0 and 4.0 m away from the tree base were varied significantly in both the treatments (tree allow to growing normally and pruning of tree up to 70 per cent plant height). Light intercepted by crop under tree-crop system at 0.5 m away from tree base was 21.15 to 23.56 per cent less compared to pure crop at various dates after sowing during 2001. Similarly in case of tree allowed to grow normally, light intercepted by the crop was 37.52 to 42.60 per cent less at 0.5 m away from tree base as compared to pure crop. The difference in light interception was gradually reduced with increasing distances from tree base in both the treatments. In tree-crop system the effect of tree on light interception was more visible at 0.5 m away from tree base compared to 1.0, 2.0, 3.0 and 4.0 m away from tree base. Similar results were also obtained during 2002. The light interception in crop at 0.5, 1.0, 2.0, 3.0 and 4.0 m away from tree base were highly significant under both treatments.

4.5.2 Light intercepted by an intercrop (mustard) in tree-crop system

The light interception in crop was 7.10 to 42.25 and 6.02 to 36.69 per cent under pruning of tree up to 70 per cent plant height and tree allowed to grow normally respectively at 0.5 m away from tree base (Table 4.5.2). These values were significantly less as compared to light intercepted by the crop at 1.0, 2.0, 3.0 and 4.0 m away from tree base. The light interception was 26.83 to 50.55 per cent less in pruning of tree up to 70

Table 4.5 Light intercepted (%) by the crops at different distances from the tree base in *Albizia procera* based agroforestry system in selected treatment

Table 4.5.1 Light intercepted by the blackgram (%)

Duration	Pruning of tree up to 70% plant height					Tree allow to grow normally					Pure crop
	0.5 m	1.0 m	2.0 m	3.0 m	4.0 m	0.5 m	1.0 m	2.0 m	3.0 m	4.0 m	
	2001										
30 DAS	23.09	23.63	27.70	28.38	28.77	17.34	18.33	27.29	27.65	28.41	30.21
60 DAS	35.15	36.40	40.24	41.40	41.75	28.14	29.36	39.57	40.19	41.34	45.04
At harvest	34.17	35.12	38.71	39.44	40.34	25.35	26.32	38.20	38.85	40.29	43.34
	2002										
30 DAS	19.20	20.14	22.16	22.31	23.23	13.58	14.71	20.33	21.37	22.40	25.12
60 DAS	31.13	31.65	51.78	52.52	53.60	28.41	29.45	50.34	52.35	52.60	55.71
At harvest	28.25	29.67	43.21	45.33	46.45	25.54	26.51	42.17	45.37	46.37	50.30

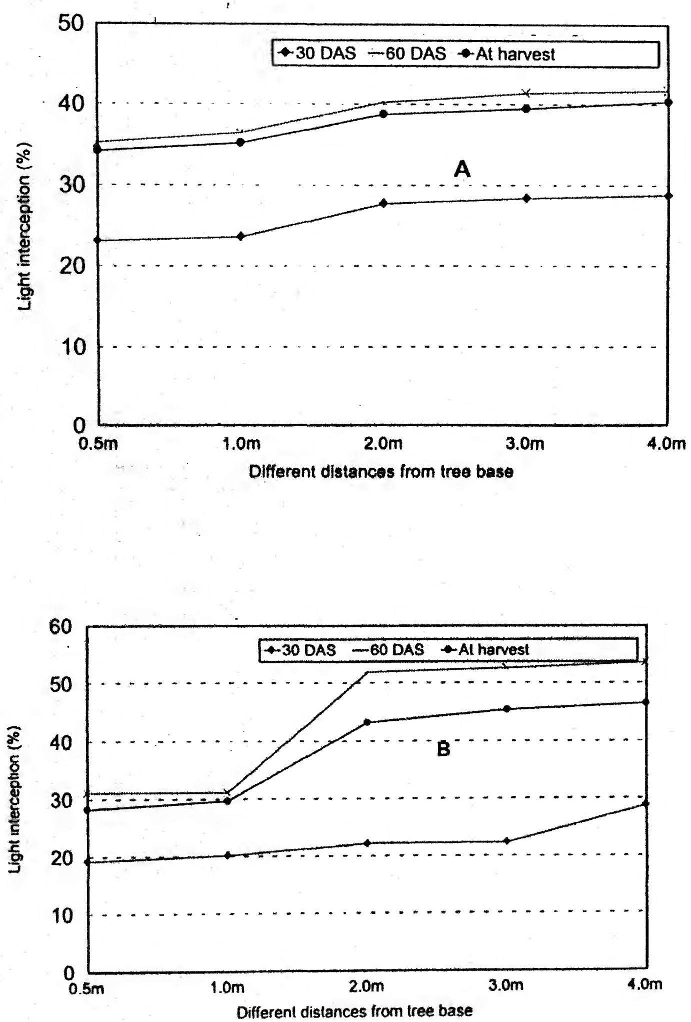


Fig. 4.1 Light intercepted by crop (blackgram) in tree-crop system under pruning of tree up to 70%plant height (A and B = Year 2001 and 2002, respectively)

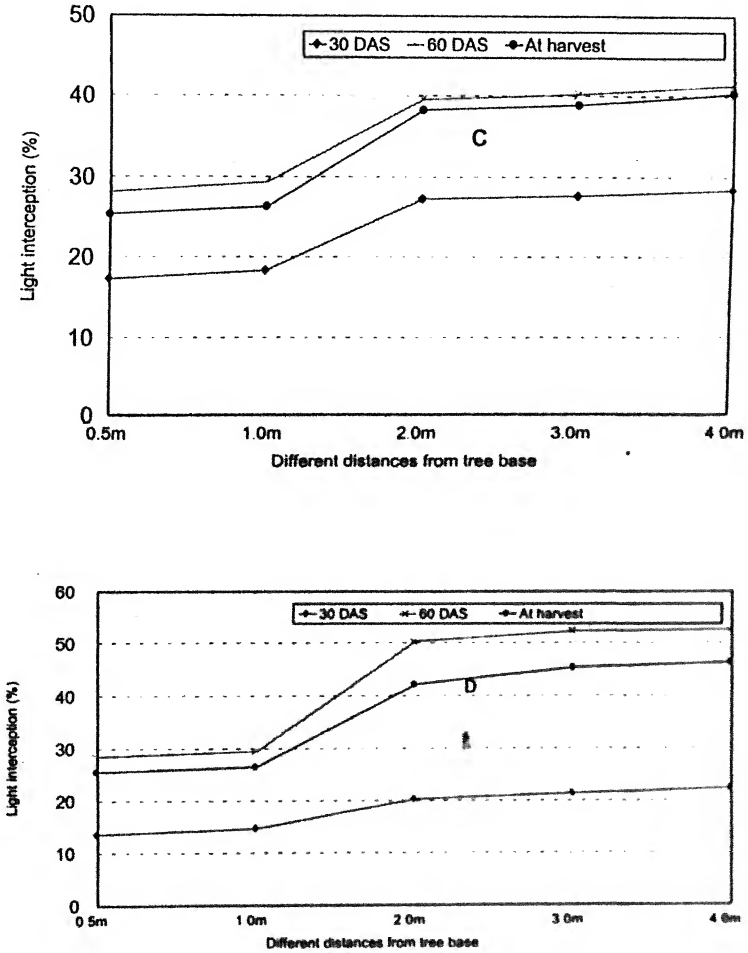


Fig. 4.2 Light intercepted by crop (blackgram) in tree-crop system under tree allowed to grow normally (C and D = Year 2001and 2002, respectively)

Table 4.5.2 Light intercepted by the mustard (%)

Duration	Pruning of tree up to 70% plant height					Tree allow to grow normally					Pure crop
	0.5 m	1.0 m	2.0 m	3.0 m	4.0 m	0.5 m	1.0 m	2.0 m	3.0 m	4.0 m	
						2000-01					
15 DAS	7.10	7.39	9.33	9.87	10.40	6.02	6.35	8.44	9.35	10.46	13.20
30 DAS	8.08	8.24	9.64	10.41	10.40	7.36	7.42	9.61	9.88	10.61	16.34
60 DAS	22.11	22.37	24.13	25.22	25.78	18.58	19.24	23.83	25.32	25.42	32.41
90 DAS	42.25	42.59	48.42	48.53	49.39	36.69	37.27	47.53	48.46	48.64	57.75
At harvest	34.11	34.80	44.31	45.33	46.17	30.22	31.38	44.31	45.17	45.19	54.42
						2001-02					
15 DAS	7.11	7.36	10.59	11.22	11.46	6.14	6.46	9.44	11.14	11.36	15.01
30 DAS	16.39	16.62	23.24	24.47	24.51	14.31	14.65	22.24	24.32	24.50	27.32
60 DAS	18.24	18.35	27.66	28.34	28.61	15.63	16.50	26.66	28.22	28.45	34.14
90 DAS	45.52	46.30	61.68	62.46	62.89	41.17	41.66	60.35	62.29	62.64	68.74
At harvest	35.39	36.53	43.71	44.71	45.62	29.49	31.57	43.24	44.26	44.51	51.10

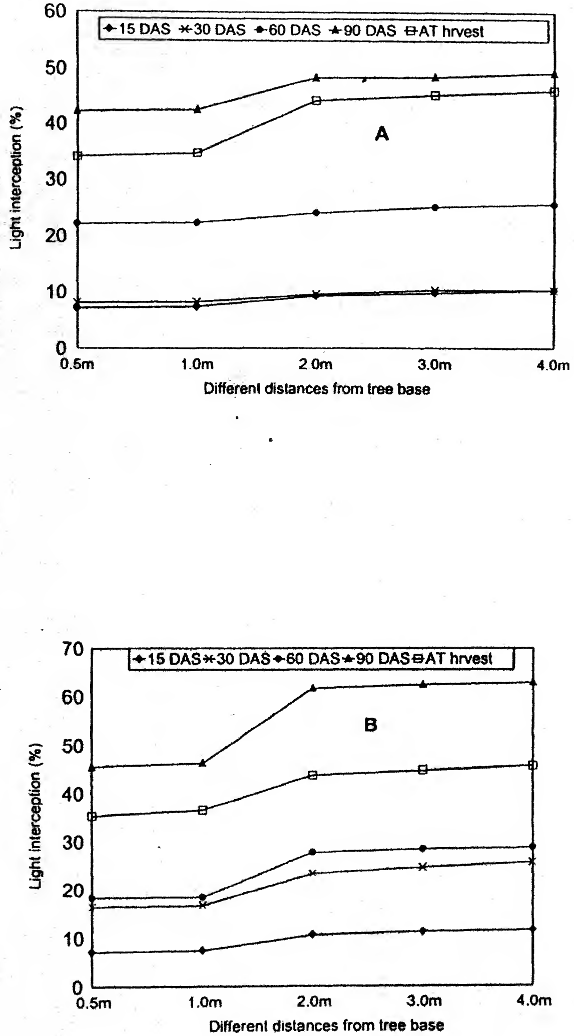


Fig.4.3 Light intercepted by crop (mustard) in tree-crop system under pruning of tree up to 70% plant height (A and B =Year 2000-01 and 2001-02, respectively)

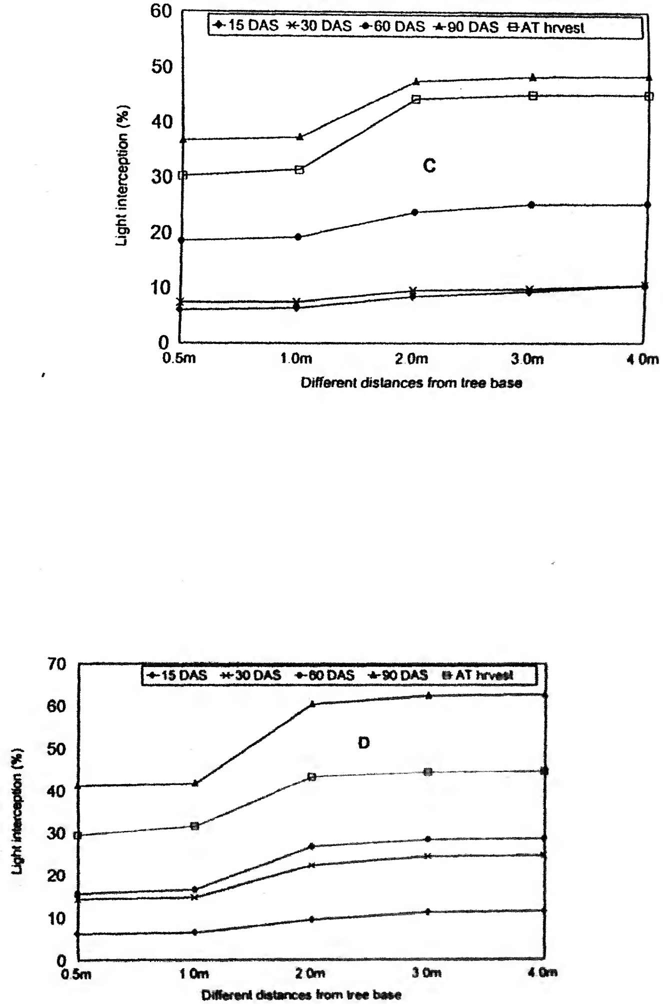


Fig.4.4 Light intercepted by crop (mustard) in tree-crop system under tree allowed to grow normally (C and D = Year 2000-01 and 2001-02, respectively)

per cent plant height and 36.46 to 54.95 per cent less in tree allowed to grow normally at 0.5 m away from tree base compared to pure crop during 2000-01. In general, the light interception increased gradually with increasing distances from tree base. Overall the effect of tree on light availability to the intercrop was seen up to first and second row in both the treatments (pruning of tree up to 70 per cent plant height and tree allow to growing normally).

In tree-crop system light intercepted by the crop was 52.63, 40.00, 46.57, 33.77 and 30.74 per cent at 15, 30, 60, 90 days after sowing and at harvest respectively under pruning of tree up to 70 per cent plant height as compared to pure crop during 2001-02. Similarly in case of tree allowed to grow normally, the light interception in crop at 0.5 m away from tree base was 59.09, 47.62, 54.21, 40.10, and 42.28 per cent less as compared to pure crop at 15, 30, 60, 90 days after sowing and at harvest, respectively.

4.6 Effect on microclimate in tree-crop system

4.6.1 Kharif season

4.6.1.1 Temperature

Changes in temperature due to tree under tree allowed to grow normally at different dates after sowing was less as compared to pruning of tree up to 70 per cent plant height. In tree-crop system on an average the temperature was 4.86 and 8.81 per cent less during 2001 and 2002, respectively compared to open field at different dates after sowing. Similarly in case of tree allowed to grow normally, temperature was 6.80 and 12.85 per cent less during 2001 and 2002, respectively as compared to open field at different dates after sowing (Table 4.6.1).

4.6.1.2 Humidity

Humidity in tree-crop system was higher than open field (Table 4.6.2). In case of tree allowed to grow normally, humidity under tree canopy was 25.81 and 30.55 per cent higher than open field during 2001 and 2002, respectively irrespective of different dates after sowing. Similarly in case of pruning of tree up to 70 per cent plant height, humidity

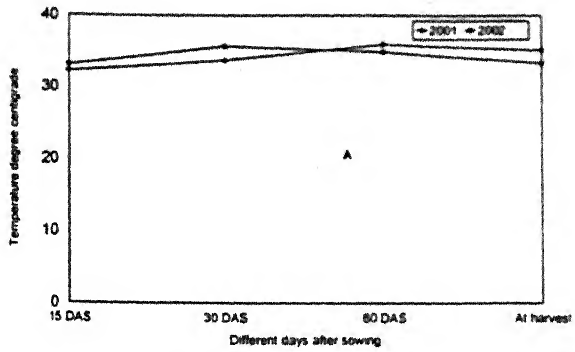
Table 4.6 Micro-climatic effect on in tree-crop system (temperature and humidity)

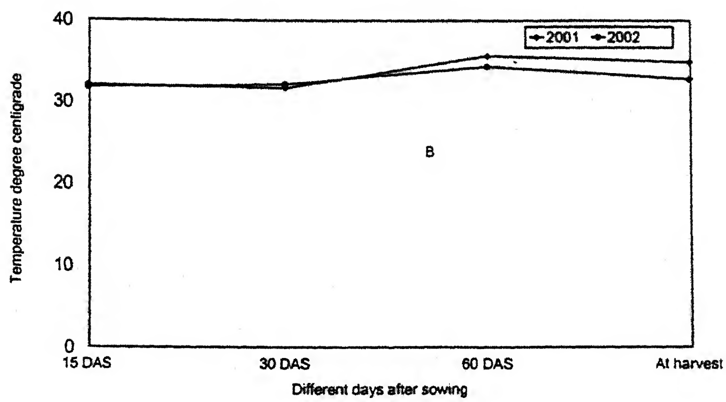
Table 4.6.1 Temperature under tree canopy in selected treatment (blackgram) and open field (^0C)

Month	Pruning of tree up to 70% plant height		Tree allow to grow normally		Open field	
	2001	**2002**	**2001**	**2002**	**2001**	**2002**
15DAS	32.21	33.10	32.04	31.70	33.74	34.54
30DAS	33.72	35.68	31.68	32.16	34.14	36.23
60DAS	35.94	34.88	35.62	34.33	37.78	39.43
At harvest	35.12	33.35	34.85	32.76	38.31	40.06

Table 4.6.2 Humidity under tree canopy in selected treatment (blackgram) and open field (%)

Month	Pruning of tree up to 70% plant height		Tree allow to grow normally		Open field	
	2001	**2002**	**2001**	**2002**	**2001**	**2002**
15DAS	69.40	62.05	73.02	69.45	60.10	58.55
30DAS	66.76	67.48	71.59	72.45	57.08	52.47
60DAS	58.64	59.00	62.04	62.16	49.14	45.33
At harvest	52.57	69.33	56.18	73.16	42.57	56.00





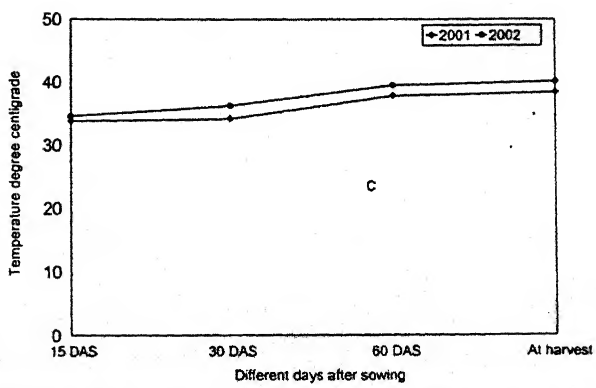
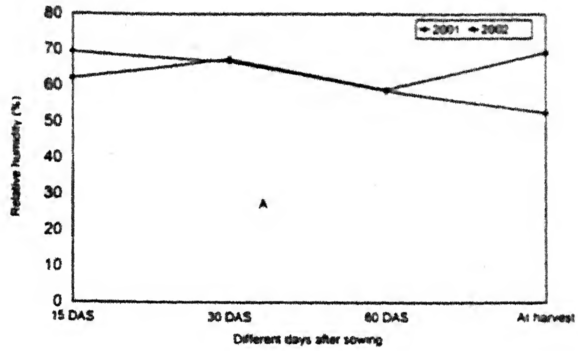
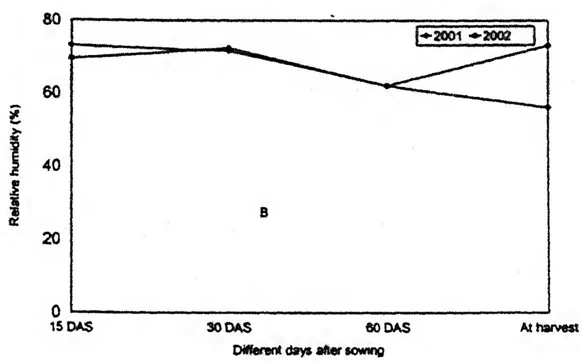


Fig. 4.5 Changes in temperature under tree-crop system during kharif season (blackgram) and in open field
Note: A= Pruning of tree up to 70% plant height B = Tree allowed to grow normally C= Open field





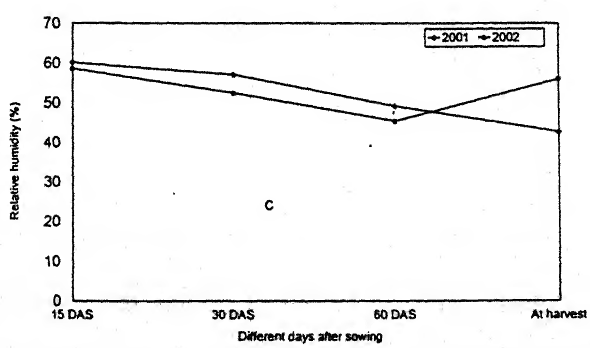


Fig. 4.6 Changes in humidity under tree-crop system during kharif season (blackgram) and in open field
Note: A= Pruning of tree up to 70% plant height B = Tree allowed to grow normally C = Open field

under tree canopy at different dates after sowing was 18.42 and 21.43 per cent higher during 2001 and 2002, respectively as compared to open field (Table 4.6.2).

4.6.2 Rabi season

4.6.2.1 Temperature

Changing pattern in temperature due to tree in rabi season was almost similar to kharif. However the temperature in case of tree allowed to grow normally was 2.01 to 6.61 per cent less at different dates after sowing compared to open field during 2000-01 and these values varied from 7.73 to 16.95 per cent during 2001-02 at different dates after sowing. Similarly in case of pruning of tree up to 70 per cent height, the temperature under tree canopy was 0.31 to 2.51 per cent less compared to open field at different dates after sowing. In tree-crop system the temperature under tree canopy was 3.76 to 14.82 per cent less as compared to open field at different dates after sowing (Table 4.6.3).

4.6.2.2 Humidity

The humidity under tree canopy in both the treatments (tree allowed to grow normally and pruning of tree up to 70 per cent plant height) was higher than open field at different dates after sowing during both the years (Table 4.6.4).

4.7 Shade length

4.7.1 Kharif season

The shade of tree was 2.76 meter from tree base during September 2001 and in same month 2002 shade length was 3.17 meter from tree base. The length of shade was varied with different months of the year (Table 4.7.1).

4.7.2 Rabi season

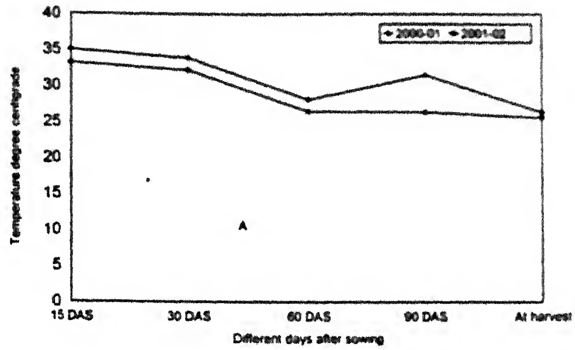
In rabi season the shade of tree was 1.56 meter in January, 2001 and in same month of 2002, the shade of tree was 2.90 meter (Table 4.7.2). The length of shades increased with increasing age of tree and it varied with different months of the year.

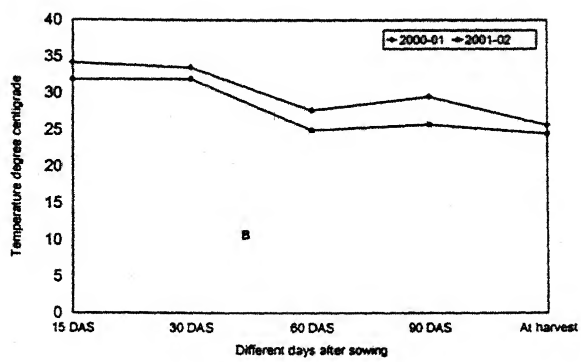
Table 4.6.3 Temperature under tree canopy in selected treatment (mustard) and open field (^{0}C)

Month	Pruning of tree up to 70% plant height		Tree allow to grow normally		Open field	
	2000-01	**2001-02**	**2000-01**	**2001-02**	**2000-01**	**2001-02**
15 DAS	35.00	33.20	34.12	31.83	35.90	34.50
30 DAS	33.87	32.16	33.47	31.91	34.37	35.30
60 DAS	28.10	26.47	27.65	24.95	28.22	28.96
90 DAS	31.50	26.37	29.51	25.71	31.60	30.96
At harvest	26.39	25.64	25.63	24.49	27.07	27.95

Table 4.6.4 Humidity under tree canopy in selected treatment (mustard) and open field (%)

Month	Pruning of tree up to 70% plant height		Tree allow to grow normally		Open field	
	2000-01	**2001-02**	**2000-01**	**2001-02**	**2000-01**	**2001-02**
15 DAS	24.22	27.20	25.01	29.43	20.34	23.60
30 DAS	30.05	28.11	31.25	30.80	26.40	22.66
60 DAS	38.15	44.67	40.33	44.80	35.59	37.66
90 DAS	37.40	45.00	39.87	46.07	27.87	30.66
At harvest	32.56	46.75	34.11	47.51	25.56	31.33





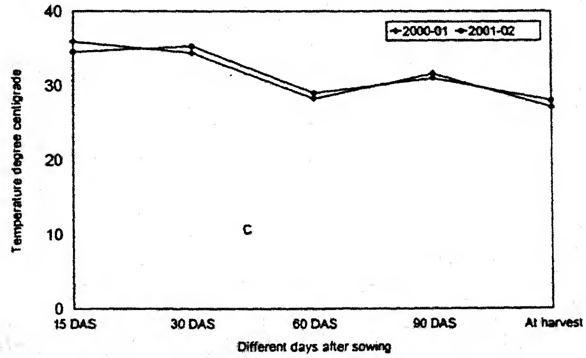
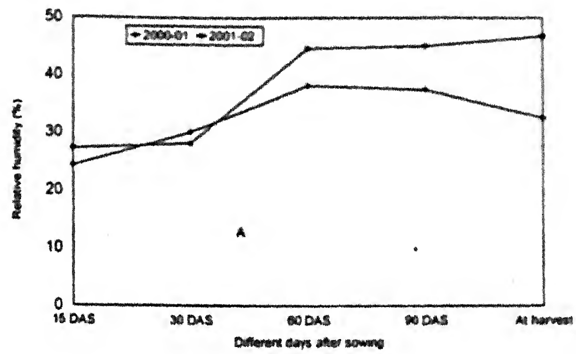
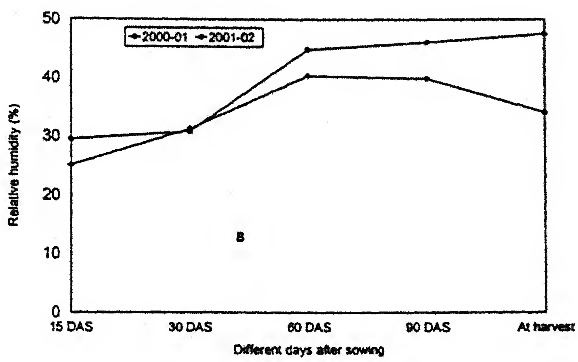


Fig. 4.7 Changes in temperature under tree-crop system during rabi season (mustard) and in open field
Note: A= Pruning of tree up to 70% plant height B = Tree allowed to grow normally C= Open field





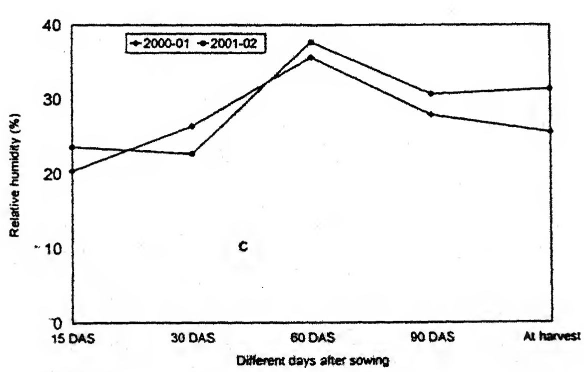


Fig. 4.8 Changes in humidity under tree-crop system during rabi season (mustard) and in open field
Note: A= Pruning of tree up to 70% plant height B = Tree allowed to grow normally C = Open field

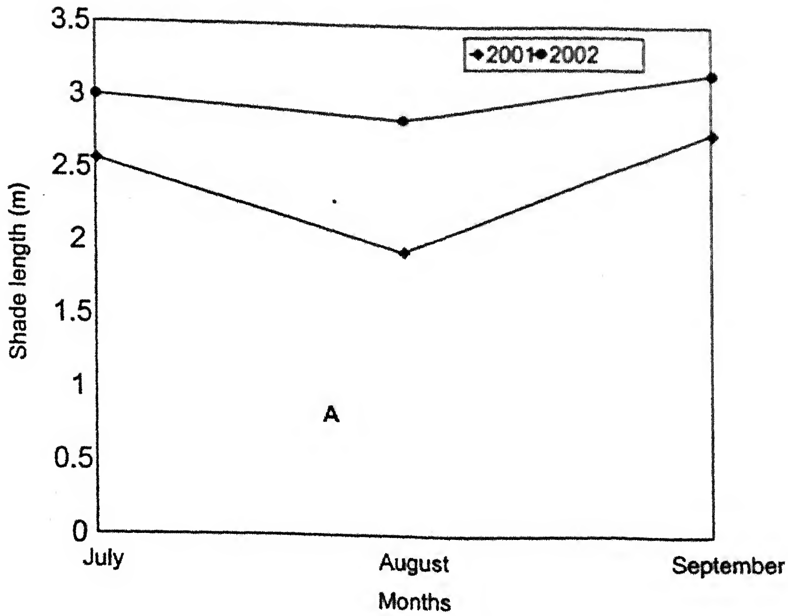
Table 4.7 Shade length of *Albizia pracera* in selected treatment (m)

Table 4.7.1 Khrif season

Month	Pruning of tree up to 70% plant height		Tree allow to grow normally	
	2001	**2002**	**2001**	**2002**
July	2.56	3.00	1.83	2.96
August	1.94	2.85	2.65	3.02
September	2.76	3.17	2.33	3.24

Table 4.7.2 Rabi season

Month	Pruning of tree up to 70% plant height		Tree allow to grow normally	
	2000-01	**2001-02**	**2000-01**	**2001-02**
October	0.92	1.55	1.02	2.13
November	0.95	1.61	1.14	2.51
December	1.51	2.74	1.19	2.61
January	1.56	2.90	1.08	2.20
February	1.48	2.74	1.12	2.23



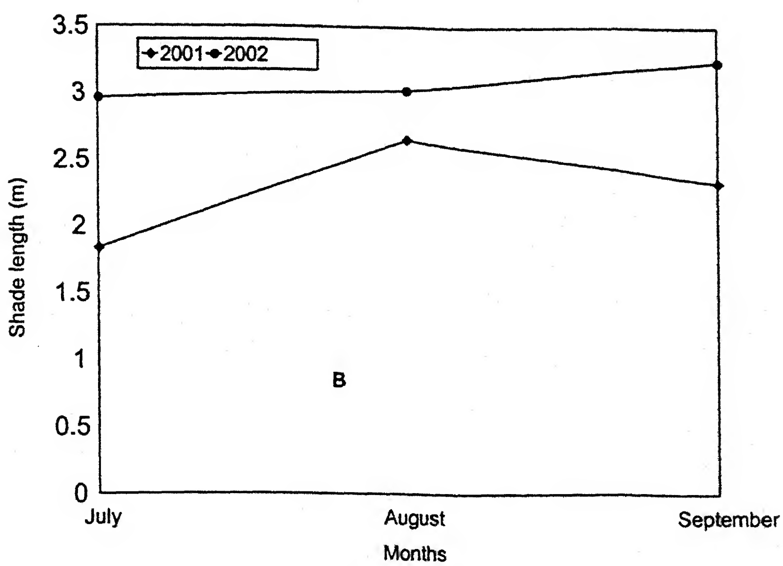
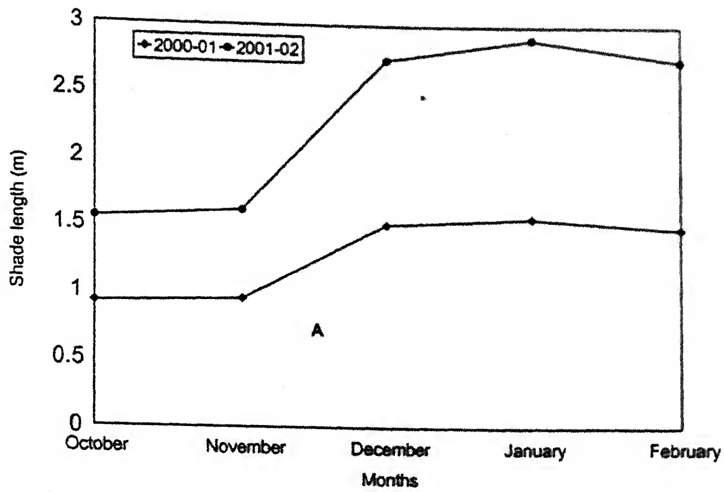


Fig. 4.9 Shade length of tree during kharif season under pruning of tree up to 70 % plant height (A) and Tree allowed to grow normally (B)



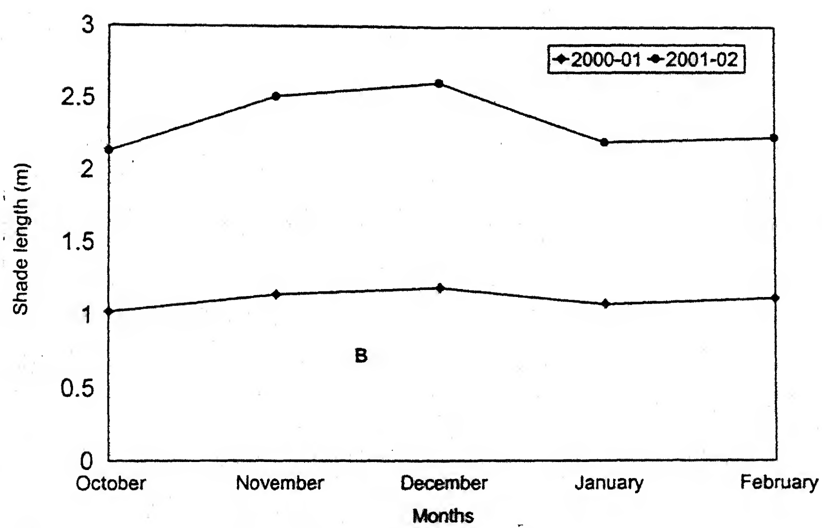


Fig. 4.10 Shade length of tree during rabi season under pruning of tree up to 70 % plant height (A) and Tree allowed to grow normally (B)

4.8 Soil moisture

Moisture contents at different distances and depths of soil have been given in Table 4.8, which indicate that during 2000-01 and 2001-02 the moisture content in soil at 0.5 m and 1.0 m was slightly less as compared to 2.0 m and 3.0 m away from tree base at 0-15 cm soil depth. Similar results were also found in case of 15-30 cm soil depth during both the years. Among different treatments, the moisture content was less in those treatments, in which crop received only one-irrigation at flowering compared to crop received irrigation as per their requirement. In another condition, where tree and crop was separated by soil barrier, the moisture content at 0.5, 1.0, 2.0 and 3.0 m away from tree base was almost similar under 0-15 and 15-30 cm soil depth.

4.9 Root length density and specific root length

Root length density (cm root length / cm^3 soil volume) and specific root length (m root length / g dry weight of root) after one and two years planting have been given in Table 4.9, which showed that soil barrier was fully able to restrict the movement of root. But in case of other treatments (tree allowed to grow normally and pruning of tree up to 70 per cent plant height) the horizontal movement of roots after a year of planting was observed up to 1.0 m. Although the root length density was higher 0.5 m away from tree base and it decreased with increasing distance from tree base. Similarly, specific root length was less at 0.5 m away from tree base and it increased with increasing distances from tree base. The root length density and specific root length were less in pruning of trees up to 70 per cent plant height as compared to tree allowed to grow normally.

4.10 Pruned biomass

After a year of planting the pruned biomass (leave and twigs) of tree was 0.43 to 1.19 kg $tree^{-1}$ and this biomass was two and three times more after two years of plantation (Table 4.10).

Table 4.8 Soil moisture depletion pattern (0-15 and 15-30 cm soil depth) in tree-crop system during the rabi season at different distances from the tree base (average of four months, November to February)

Treatment	Soil moisture per cent							
	2000-01							
	0-15 cm soil depth				15-30 cm soil depth			
	0.5 m	1.0 m	2.0 m	3.0 m	0.5 m	1.0 m	2.0 m	3.0 m
Tree allow to grow normally + crop	9.33	9.77	10.31	10.99	11.67	11.90	12.23	12.61
Pruning of tree up to 70% plant height + crop	10.44	10.91	11.11	12.01	11.75	12.25	12.72	13.46
Tree allow to grow normally + soil barrier + crop	10.66	10.86	11.06	11.19	12.87	12.95	13.19	13.67
Pruning of tree up to 70% height + soil barrier + crop	11.20	11.44	11.64	11.99	13.49	13.53	13.51	14.05
Tree allow to grow normally + crop + irrigation as per requirement of crop	11.85	12.54	13.10	13.69	14.02	14.47	15.04	15.58
Pruning of tree up to 70% plant height + crop + irrigation as per requirement of the crop	12.74	13.24	14.00	14.72	14.56	14.85	15.86	16.48
	2001-02							
Tree allow to grow normally + crop	9.11	9.75	10.19	11.06	10.54	11.27	11.80	12.32
Pruning of tree up to 70% plant height + crop	9.46	10.18	10.97	11.42	11.10	11.92	12.17	13.25
Tree allow to grow normally + soil barrier + crop	10.65	10.62	10.36	10.52	11.87	11.86	11.46	12.41
Pruning of tree up to 70% height + soil barrier + crop	11.18	11.26	11.56	11.58	12.63	12.81	12.76	13.05
Tree allow to grow normally + crop + irrigation as per requirement of crop	12.07	12.46	12.84	12.98	13.72	14.37	15.01	15.52
Pruning of tree up to 70% plant height + crop + irrigation as per requirement of the crop	12.26	12.74	13.63	13.62	14.70	15.01	15.38	16.23

Table 4.9 Root length density and specific root length at different distances from the tree base *Albizia procera* based agroforestry system in selected treatment

Selected treatment	Root length density (cm root length / cm^3 soil volume)			Specific root length (meter root length / g dry weight of roots)		
	0.5 m	**1.0 m**	**2.0 m**	**0.5 m**	**1.0 m**	**2.0 m**
		2001			**2001**	
Tree allow to grow normally + crop	0.054	0.039	-	5.367	6.700	-
Pruning of tree up to 70% plant height + crop	0.042	0.031	-	5.112	6.354	-
Tree allow to grow normally + soil barrier + crop	-	-	-	-	-	-
Pruning of tree up to 70% height + soil barrier + crop	-	-	-	-	-	-
		2002			**2002**	
Tree allow to grow normally + crop	0.092	0.066	0.037	7.978	9.841	10.725
Pruning of tree up to 70% plant height + crop	0.081	0.064	0.035	7.399	8.908	11.072
Tree allow to grow normally + soil barrier + crop	-	-	-	-	-	-
Pruning of tree up to 70% height + soil barrier + crop	-	-	-	-	-	-

Table 4.10 Pruned biomass of *Albizia procera* in selected treatment (kg tree^{-1})

Selected treatment	Biomass	
	2001	**2002**
Pruning of tree up to 70% plant height + crop	0.43	1.98
Pruning of tree up to 70% height + soil barrier + crop	1.19	2.76
Pruning up to 70% plant height + crop + irrigation as per requirement of the crop	1.19	4.39

4.11 Changes in physico-chemical properties of soil

Soil fertility changes due to treatments after two years have been depicted in Table 4.11.1, which revealed that at 0-15 and 15-30 cm soil depth, changes in pH, electrical conductivity and organic carbon were very much nominal as compared to initial value. However, the pH, electrical conductivity and organic carbon were higher at 0–15 cm soil depth as compared to 15-30 cm soil depths under different treatments. The values of these parameters at different distances from tree base were also similar to each other. After two year of experimentation, no definite trend was observed due to treatment at different distances from tree base under 0-15 and 15-30 cm soil depths.

Similar results were also found in case of available nitrogen, phosphorus and potassium (Table 4.11.2). The available nitrogen, phosphorus and potassium were 158.20 to 169.20 kg ha^{-1}, 9.08 to 11.70 kg ha^{-1} and 132.57 to 139.41 kg ha^{-1}, respectively. These values were slightly higher than initial value (157.40, 8.58 and 132.20 kg ha^{-1} available nitrogen, phosphorus and potassium, respectively). The content of nitrogen, phosphorus and potassium was less at 15-30 cm soil depth compared to 0-15 cm soil depth.

Table 4.11 Changes in physico-chemical properties of soil (2000 to 2002)

Table 4.11.1 Soil pH, electrical conductivity and organic carbon

Treatment	pH				Electrical conductivity (d Sm^{-1} at 25 x C)				Organic carbon (%)			
	Distances from the tree base											
	0.5m	1.0 m	2.0 m	3.0 m	0.5 m	1.0 m	2.0 m	3.0 m	0.5 m	1.0 m	2.0 m	3.0 m
	0-15 cm soil depth											
Tree allow to grow normally + crop	6.62	6.65	6.61	6.67	0.08	0.06	0.07	0.08	0.51	0.51	0.52	0.51
Pruning of tree up to 70% plant height + crop	6.79	6.79	6.78	6.69	0.07	0.06	0.08	0.05	0.50	0.52	0.51	0.52
Tree allow to grow normally + soil barrier + crop	6.80	6.79	6.69	6.79	0.08	0.07	0.06	0.08	0.52	0.51	0.52	0.51
Pruning of tree up to 70% height + soil barrier + crop	6.80	6.82	6.75	6.76	0.07	0.05	0.07	0.07	0.53	0.53	0.52	0.51
Tree allow to grow normally + crop + irrigation as per requirement of crop	6.70	6.71	6.69	6.72	0.06	0.06	0.07	0.07	0.54	0.52	0.51	0.52
Pruning of tree up to 70% plant height + crop + irrigation as per requirement of the crop	6.82	6.80	6.71	6.64	0.07	0.06	0.09	0.07	0.53	0.51	0.52	0.52
Pure tree	6.58				0.07				0.52			
Pure crop	6.72				0.06				0.52			
Initial	6.57				0.08				0.51			
	15-30 cm soil depth											
Tree allow to grow normally + crop	6.60	6.61	6.60	6.65	0.05	0.06	0.07	0.05	0.36	0.34	0.34	0.34
Pruning of tree up to 70% plant height + crop	6.65	6.72	6.64	6.61	0.06	0.06	0.07	0.05	0.34	0.35	0.39	0.34
Tree allow to grow normally + soil barrier + crop	6.76	6.74	6.66	6.75	0.08	0.05	0.05	0.07	0.37	0.37	0.35	0.35
Pruning of tree up to 70% height + soil barrier + crop	6.74	6.68	6.71	6.67	0.07	0.05	0.07	0.05	0.38	0.38	0.36	0.34
Tree allow to grow normally + crop + irrigation as per requirement of crop	6.63	6.68	6.67	6.68	0.05	0.06	0.07	0.06	0.37	0.38	0.38	0.37
Pruning of tree up to 70% plant height + crop + irrigation as per requirement of the crop	6.78	6.69	6.69	6.68	0.06	0.06	0.08	0.05	0.34	0.37	0.34	0.35
Pure tree	6.57				0.06				0.35			
Pure crop	6.69				0.05				0.35			
Initial	6.81				0.06				0.34			

Table 4.11.2 Available nitrogen, phosphorus and potassium (kg ha^{-1})

Treatment	Available nitrogen				Available phosphorus				Available potassium			
	Distances from the tree base											
	0.5 m	1.0 m	2.0 m	3.0 m	0.5 m	1.0 m	2.0 m	3.0 m	0.5 m	1.0 m	2.0 m	3.0 m
0-15 cm soil depth												
Tree allow to grow normally + crop	160.50	162.20	165.50	169.00	10.67	9.77	9.85	10.87	134.40	136.00	137.24	135.23
Pruning of tree up to 70% plant height + crop	163.40	162.00	165.50	169.00	10.09	9.64	9.92	9.48	133.01	135.21	136.14	134.22
Tree allow to grow normally + soil barrier + crop	163.80	158.20	163.40	166.70	11.70	11.06	10.87	9.11	135.02	138.41	134.41	136.51
Pruning of tree up to 70% height + soil barrier + crop	163.80	159.30	162.20	164.40	10.53	9.45	9.08	10.66	134.10	136.45	138.28	134.21
Tree allow to grow normally + crop + irrigation as per requirement of crop	164.20	164.10	166.30	169.20	9.87	9.87	9.54	9.66	134.04	133.24	139.41	135.14
Pruning of tree up to 70% plant height + crop + irrigation as per requirement of the crop	162.20	165.70	163.80	161.07	9.09	9.75	10.00	10.54	135.21	132.57	135.21	137.42
Pure tree	159.00				8.61				132.21			
Pure crop	164.20				10.95				137.24			
Initial	157.40				8.58				132.20			
15-30 cm soil depth												
Tree allow to grow normally + crop	142.00	146.70	143.80	146.70	7.58	8.47	7.10	8.20	123.01	128.01	124.54	125.21
Pruning of tree up to 70% plant height + crop	143.80	149.60	149.00	143.80	7.25	7.25	7.00	7.24	122.14	127.01	125.34	126.34
Tree allow to grow normally + soil barrier + crop	148.30	145.50	143.40	142.00	6.58	8.58	8.01	7.34	124.54	124.11	123.32	125.34
Pruning of tree up to 70% height + soil barrier + crop	143.80	143.40	143.30	145.20	6.86	7.12	7.16	7.05	125.21	122.30	123.03	128.24
Tree allow to grow normally + crop + irrigation as per requirement of crop	140.00	145.50	145.30	149.30	5.98	7.14	6.78	6.85	122.32	124.04	128.27	126.37
Pruning of tree up to 70% plant height + crop + irrigation as per requirement of the crop	155.20	149.50	152.50	152.00	6.12	7.01	6.45	7.34	123.05	123.01	126.25	127.38
Pure tree	143.52				6.47				123.00			
Pure crop	145.30				7.12				126.05			
Initial	138.01				5.24				122.01			

Discussion

CHAPTER V

DISCUSSION

A field experiment was conducted for two years (2000-02) at Research Farm of National Research Centre for Agroforestry, Jhansi to quantify the competitive effect of soil moisture, light and nutrients and to see the effect of management practices on minimize competition and maximize complementarity in tree-crop system. The results obtained during field experimentation have been discussed in this chapter along with support of field observations of elsewhere on similar type of research.

5.1 Effect of intercrops (blackgram and mustard) on growth of tree (*Albizia procera*)

The growth performance of pure tree was better to that tree-crop system during first year because mustard crop overlapped the trees and both tree and crop competed for aboveground growth resources from same level during first year. The results here were similar to the observation made with agricultural crops such as sugarcane, maize, arhar, jowar etc. interplanted with tree and their related cultivation practices do affect the trees in several ways and they compete with sapling for nutrients, water, light and space, particularly during first few years (Dwivedi, 1992). In an another study Sharma (1988) also observed that several tree species interplanted with sugarcane, maize and jowar in Haryana and western Uttar Pradesh, the growth rate of saplings planted on the bund was less in comparison to those growing in open. However, the results are different from silvipasture in which intercropping grasses had no effect on the growth of *Azadirachta indica* and *Acacia nilotica* (Muthana *et al.*, 1985). Contrary to this observation, the growth of *Acacia tortilis* was suppressed by *Cenchrus* species during the first three year but after that the trees attained better growth rates with grass (Shankarnarayana *et al.*, 1987).

During second year, the growth of trees was some time better/similar in tree-crop system to that pure tree. *Albizia procera* is fast growing tree and their root systems are well developed after a year of planting. Under such situation the effect of intercrop on the trees is considerably reduced and slowly the trees become more dominant and their effect

on the agricultural crops become more relevant. In general, the growth performance of trees was obviously better in those treatments in which trees were growing normally and associated crop (mustard) received irrigation as per their requirement compared to other treatments (one irrigation provided to the associated crop at flowering) during both the years. This is probably due to *Albizia procera* benefited from the irrigation given to the mustard crop. The results are in conformity with those obtained with eucalyptus seedlings in which fertilizer and weeding given to the agricultural crop also benefited to the growth of eucalyptus seedling when compared to the eucalyptus monoculture (Couto and Gomes, 1995). Pruning of tree up to 70 per cent plant height and soil barrier did not show any influence on the growth of tree after one or two years after plantation. It was mainly due to the space available within the barrier was sufficient for the growth of tree and pruning up to 70 per cent plant height was able to maintain the growth of tree in early age. Similar views were also expressed by Roy and Deb Roy, 1986; Handa and Rai, 2001 in case of *Albizia amara, Albizia procera, Hardwickia binata and Anogeisus spp.* These species are able to tolerate even 70 to 75 per cent of the canopy removal.

5.2 Effect of tree on growth of intercrop (blackgram)

In general, germination in first row from the tree base was less compared to second, third and fourth rows from tree base after one year of tree plantation. However, in pruning (up to 70 per cent plant height) the germination was slightly higher than the tree was allowed to grow normally during both the years but the differences were not significant. Sharma *et al.* (2000) also stated that the reduction in plant population of wheat crop due to poplar at 0-3 m distances from tree line was 34.2 per cent over control and this reduction was less with increasing distances from tree line. Overall, the germination of crop in pure crop was higher as compared to tree-crop system irrespective of treatments and different rows from the tree base.

After one year of planting, the effect of tree on height of crop was observed only up to second row and this effect was more pronounced during second year. The plant height of crop was significantly higher in first and second row from tree base under pruning of tree up to 70 per cent plant height + irrigation of crop as per their requirement as

compared to other treatments. The plant height of crop was almost similar in third and fourth rows. In some cases plant height was better in third row and in some cases better in fourth row, which indicate that tree did effect the crop up to second row from tree base after one or two years of planting. Many other studies had also revealed that the level of effect on growth and yield of crop by tree component in tree-crop system under different level of stresses and caused by growth behaviour and age of tree (Ralhan *et al.*, 1992; Puri and Sharma, 2002; Puri *et al.*, 1994; Schroth, 1999).

The effect of tree on branching of crop indicated that number of branches plant^{-1} was less in first row from tree base compared to second row irrespective of treatments. It was mainly due to the growth of tree was not so enough after two years of plantation to compete with crop beyond second row of crop. Effect of tree on crop was decreased with increasing distance from tree base. Among different treatments, the branching in crop under pruning of tree up to 70 per cent plant height was significantly higher in first year as compared to other treatments but the differences were significant during second year. Higher branching in this treatment was might be due to the pruning of tree up to 70 per cent plant height permitted more light to understorey crop as compared to naturally growing trees. The competitive effect of tree on crop was seen only up to first row and very little effect was noticed on second row during first and second year. Soil barrier had significant effect on branching of crop after a year of planting but the differences were not significant during second year. However in those treatments in which a soil barrier (GI sheet) was installed in between tree and crop, the associated crop was better in branching as compared to without soil barrier either trees were growing normally or pruned up to 70 per cent plant height. It indicated that soil barrier did not allow penetrating tree roots in crop area, which minimized the competitive effect for soil moisture and nutrients in between tree and crop.

5.3 Effect of tree on yield and yield attributes of intercrop (blackgram)

The effect of tree line on pod formation was more obvious on first row and in this row the pods were 4.06 to 9.44 per cent less as compared to second row of crop from tree base during 2001.This difference was higher (1.34 to10.49per cent) during 2002. Number

of pod increased gradually with increasing distances from tree base. This may be due to the fact that tree canopy during first and second year tree could not affect the penetration of light beyond the second row from tree base. Light availability is the most important limiting factor for the performance of under storey annual crops particularly where upper storey perennial from a dense over storey canopy (Miah *et al.*, 1995). The effect of treatments was also significant on pod formation of crop in first to fourth rows during 2001 but during 2002, the differences in pod number were only significant in first and fourth row. Among all the treatments, pruning of tree up to 70 per cent plant height + irrigation as per requirement of crop and tree allowing to grow normally + irrigation as per requirement of crop were significantly better to contribute more pods plant^{-1} than other treatments but pruning of tree up to 70 per cent plant height + irrigation as per requirement of crop was overall superior than rest of the treatments during both the years. This was mainly due to the pruning of tree up to 70 per cent plant height had minimum competition for light with crop, in other words the intercrop intercepted more light in this treatment as compared to tree allow to grow normally. Another reason of higher pod formation in this treatment, one-irrigation was provided to the crop during pod formation which significantly contributed in higher pod formation. Number of pods per plant under tree-crop system was less as compared to that pure cropping with irrespective of treatments and different rows from tree base.

Tree did not affect the seed formation in crop either near by the tree base (first row from tree base) or away from the tree base (second, third and fourth rows from tree base). However seeds pod^{-1} were comparatively higher in pruning of tree up to 70 per cent plant height irrespective of soil barrier and irrigation, but differences were not significant during both the years. In tree-crop system seeds pod^{-1} were almost similar to that pure crop during both the years.

In tree-crop system the grain yield running meter^{-1} in first row from tree base was 2.47 to 9.32 per cent less than the yield obtained in second row. Like wise the yield of second row was 5.06 to 11.05 per cent less than the yield of third row from the tree base irrespective of treatments. However the treatments effect was not significant during first year. The lower grain yield in first row was might be due to the tree canopy which could

affect the availability of light up to first row only. But the canopy of tree was not so enough to affect the crop in third and fourth row. During second year, the effect of trees on grain yield in first row was more pronounced and it was 2.42 to 22.77 per cent less than the yield obtained in second row. Similarly, the grain yield in second row was 1.65 to 7.46 per cent less than the grain yield of third row irrespective of treatments. The significant effect of treatments was observed in first, third and fourth rows from the tree base. Khybri *et al.* (1988) also recorded the depressing effect of tree up to 3 m, which subsequently increased up to 5 m with advanced age of trees. However no adverse effect on crop was recorded beyond 5 m distance from trees. Several field observation were made by Khybri *et al.*,1992; Chauhan *et al.*,1995; Yadav *et al.*,1993; Sharma *et al.*, 2000 indicated that distances of tree line from crop significantly affected the crop yield up to a distances of 4 to 6 m depending upon age and growth of tree but reduction in yield near by the tree base (0-3 m) was higher as compared to the away from tree base (4-6 m) in wheat, and mustard with various tree species. Increasing competition during second year was mainly due the more canopy development, which reduced light availability to the crop. The effect of tree on crop in initial year was more visible only up to first and second row of crop from tree base. If a quantitative effect of soil moisture, light and nutrients is calculated on grain yield of crop in first row only. It indicated that the grain yield of crop per running meter was 3.68 per cent higher in pruning of trees up to 70 per cent plant height than tree allowed to grow normally in during 2001. It means the availability of light in this treatment had contributed 3.68 per cent higher yield than tree allowed to grow normally. Several other studies also given similar observations in which they have stated that low light intensity is one of the important constraints for higher yield (Tanaka *et al.*, 1964; Stansel *et al.*, 1965; Vankateswarlu and Srinivas, 1978). In other hands, the grain yield was 10.82 per cent higher due to irrigation provided to the crop at pod formation stage as compared to moisture stress. It indicated that moisture is essentially had contributed to increase the grain yield, when rain was terminated before pod formation stage. In another situation, when the moisture and nutrients competition has been avoided by installing a soil barrier in between tree and crop, the grain yield in first row was 4.44 per cent higher than without barrier with irrespective of pruning and naturally growing trees. It means, if moisture and nutrient competition is avoided

between tree and crop the grain yield of crop certainly be increased, the amount may be less or more. Similar results were also found during the second year but the effect of moisture was nullified due to natural rain received during pod formation and maturity. Overall the grain yield running meter^{-1} in case of pure crop was 3.07 and 3.90 per cent higher than the yield received in tree-crop system irrespective of treatments during 2001 and 2002 respectively. Higher yield in pure crop was mainly due to the tree had competed for light, soil moisture and nutrients but the effect of tree during initial year was less.

Test weight of seed was maximum in pruning of tree up to 70 per cent plant height with irrigation as per requirement of the crop. The effect of treatments was significant in first row and fourth row only during 2001 and in second year the differences were not significant. No significant variation in treatment was mainly due to the moisture play an important role on seed size and during kharif season moisture was not a constraint during 2002 but during 2001 early termination of rain caused less test weight in all the treatment except those treatments, which received irrigation as per requirement of crop. The overall test weight of crop in tree-crop system was almost similar to that pure crop during both the years.

Among different treatments, the grain yield was maximum in pruning of tree up to 70 per cent plant height + irrigation given to the crop as per their requirement during both the years. In over all comparison, the pure crop yield was 6.58 and 20.71 per cent higher during 2001and 2002, respectively compared to tree-crop system. Similar results were also obtained by Odhiambo *et al.*, 1999 in which the maize yield was reduced in agroforestry treatments particularly close to the trees. For quantifying the effect of soil moisture, light and nutrients on grain yield of intercrop in tree-crop system, the grain yield of two years in tree-crop system was compared in different ways, like tree allowing to grow normally Vs pruning of tree up to 70 per cent plant height, tree allowing to grow normally + soil barrier Vs pruning of trees up to 70 per cent plant height + soil barrier, tree allowing to grow normally + irrigation as per requirement of crop Vs pruning of tree up to 70 per cent plant height + irrigation as per requirement of the crop and tree-crop system Vs pure crop. The results revealed that the grain yield of crop was 4.50 per cent

higher due to pruning than tree allowed to grow normally it indicates that the pruning facilitate more light than tree allowed to grow normally. Installing a soil barrier around the tree, contributed 3.10 per cent higher grain yield of crop either in pruning of trees up to 70 per cent plant height or tree allowed to grow normally. Impact of soil barrier was small of tree or either crop. Irrespective of root barriers, a high response to tree pruning suggested above ground competition for light dominated tree/crop interaction in agrisilviculture system in semi-arid region (Osman *et al.*, 1998). The grain yield of crop was 2.17 per cent higher in case of pruning of trees up to 70 per cent plant height + irrigation as per requirement of crop than tree allow to growing normally + irrigation as per requirement of crop. It was mainly due to availability of moisture depress the detrimental effect of light. The similar results were also obtained during second year but differences in yield between the treatments were gone up to 24.30 per cent, which was higher than first year. Thus observations confirmed that tree suppressed crop yields from second year onwards when trees have established themselves well. The effect of moisture on grain yield was less during second year because the crop received rain during pod formation and maturity.

5.4 Effect of tree on growth of intercrop (mustard)

Germinated plant running meter^{-1} did not vary significantly within the treatments during first year (2000-01). The similar results were also obtained during second year. However in third and fourth rows the differences were significant. The plant population near by the tree base (first row) indicates that after four months of plantation, tree (planted during July, 2000) did not exert any adverse effect on germination of crop either in first or in second row and so on. During second year also, the effect of tree was not obvious on the germination of crop. This was mainly due to fact that trees did not well established themselves and their root development was not so enough to compete for water and nutrients. Similarly the crown diameter was 0.46 to 1.26 m during this period, which could not affected much the light availability to the crop.

The maximum plant height was recorded in pruning of tree up to 70 per cent plant height irrespective of irrigation as per requirement of crop and soil barrier as compared to

tree allowed to grow normally. It indicates that after one year, the pruning of tree up to 70 per cent plant height facilitate more light interception to the crop as compared to tree allowing to grow normally. The effect of moisture was very much obvious on crop growth in those treatments in which crop received irrigation as per their requirement. Crop growth was comparatively less in those treatments in which only one irrigation was provided at flowering stage. Similar results were also obtained during 2001-02 in all treatments as well as in different rows from tree base. In general the plant height of crop was less in first row in most of the treatments during both the years. It indicates that the competitive effect of tree was only up to first row in initial years.

Branching in crop under first row was less as compared to second, third and fourth rows during both the years in all the treatments. The branches increase with increasing distances from tree base. The competitive effect of tree during second year increased simultaneously with growth of tree and the effect of tree on first row was more obvious, but this effect was not seen in third and fourth rows from tree base. Among different treatments, pruning of tree up to 70 per cent plant height + irrigation given as per requirement of crop recorded maximum branches during both the years followed by tree allow to growing normally + irrigation as per requirement of the crop. It indicated that under same amount of irrigation, the number of branches were more in pruning, it means pruning of tree compete less for light with crop, which ultimately reflect higher branching in crop. If the competition for soil moisture and nutrients are avoided by installing the soil barrier in pruning of tree up to 70 per cent plant height and tree allowed to grow normally. The effect of pruning of tree was still affective in increasing branching in crop besides soil barrier during both the years. Once again contribution of light is important or in another way the management (pruning) is also an important practice to minimize light competition. The effect of soil barrier on branching of crop was not obvious during first year but during second year, the branching in crop was at par higher than without soil barrier. In overall comparison of tree-crop system Vs pure crop under moisture stress (one irrigation given at flowering stage), number of branches in pure crop were almost similar to that intercrop with trees irrespective of treatments. Similarly, in case of no moisture stress situation, where crop received irrigation as per requirement,

number of branches in pure crop was apparently equal to that intercrop in tree-crop system.

5.5 Effect of tree on yield and yield attributes of intercrop (mustard)

The similar results were also obtained in siliquae plant^{-1} and seeds siliqua^{-1} to number of branches plant^{-1}. However, tree allowed to grow normally + irrigation as per requirement of crop and pruning of tree up to 70 per cent plant height + irrigation as per requirement of the crop had higher siliquae plant^{-1} and seeds siliqua^{-1} as compared to rest of the treatments during both the years. The values of this character were higher during 2001-02 compared to 2000-01. Those treatments received irrigation as per requirement of crop, siliquae plant^{-1} and seeds siliqua^{-1} were increased besides pruning and tree allowed to grow normally during both the years. In overall comparison of tree-crop system with pure crop under both the situations (irrigation given as per requirement of crop and one irrigation at flowering), siliquae plant^{-1} and seeds siliqua^{-1} was higher in pure crop as compared to intercrop.

The grain yield running meter^{-1} in first, second, third and fourth rows from tree base was more or less similar to each other during first year. But during second year, the grain yield in first row was less than second, third and fourth rows in all the treatments. The effect of treatments on grain yield running meter^{-1} was not significant during first year, but the differences in grain yield were significant during second year. It indicated that from second year, the competition between tree and crop has started. The grain yield meter^{-1} of crop was 6.93 per cent less in tree allowed to grow normally as compared to pruning of tree up to70 per cent plant height in first row of crop. Similarly the grain yield running meter^{-1} was about 7.16 per cent less in tree allowed to grow normally as compared to pruning of tree up to 70 per cent plant height + soil barrier. The higher yield in 70 per cent pruning might be due to the crop intercepted more light due to pruning, that induced the growth and yield attributes of crop. Similar results were also obtained in rest of the rows of crop. The influence of irrigation was more obvious on grain yield running meter^{-1}during both the years and due to irrigation as per their requirement the grain yield

was 18.53 and 16.16 per cent higher during 2000-01 and 2001-02 respectively than the crop received one-irrigation at flowering.

Overall, the grain yield of crop was similar to that pure crop either crop received one irrigation at flowering or as per requirement of crop during first year. But during second year the grain yield meter^{-1}was less as compared to that pure crop. The similar results were also obtained in case of test weight of crop.

The grain yield of crop obtained under different treatments during first year was less as compared to second year. This was mainly due to the regular fog in December and January affected the grain filling in pods. The grain yield of crop did not vary significantly during first year but the differences were significant during second year. The significant variation in yield during second year in different treatment was mainly due to the fact that after establishing the tree, tree-crop interface begun and gradually their effect on grain yield is appeared. For quantifying the effect of growth resources on crop yield in tree-crop system, it will be ideal to compare the yield received in tree allowing to grow normally Vs pruning of tree up to 70 per cent plant height clearly showed that pruning reduced more availability of light to the crop and due to pruning the grain yield was 6.77 to 14.57 per cent increased. Similar effect of pruning was also seen in other treatments.

Overall crop yield received under pure crop was 9.45 and 15.95 per cent higher to that intercropped with tree in those treatments, in which only one-irrigation was given to crop. Similarly, crop yield under pure crop was also higher than the crop yield obtained in tree-crop system, in which crop received irrigation as per their requirement. The requirement of irrigation certainly reduced the moisture competition between tree and crop besides that it increases the nutrient uptake in the crop which ultimately helps to increase the yield of crop.

5.6 Weed density and dry matter accumulation

5.6.1 Weed density and dry matter accumulation under blackgram

During kharif season, the crop was infested with *Cyperus iria*, *Digera arvensis*, *Cynodon dactylon*, *Phyllanthus niruri*, *Echinochloa crusgalli* and *Commelina*

benghalensis. The weed density and dry matter of weeds m^{-2} were varied significantly among the different treatment during both the years but during second year dry weight of weeds m^{-2} at harvest was not significant. This was mainly due to the fact that after a month of sowing, crop cover was not so good, which could not fully smother the weed but after full growth of crop its canopy coverage was able to smother the weeds. Secondly after a year of planting, trees are also well established and they also had smothering effect on weed. The effect of shade was more severe to light demanding plants than for shade tolerant plants. This could be an avenue to suppress some light demanding weeds. A reduction of weeds due to the presence of trees has been reported from many ecological zones (Yamoah *et al.*, 1986; Jama *et al.*, 1991; Rippin, 1991 and Yadav *et al.*, 1993). Apart from shading, weed suppression is also determined by factors such as land-use history, weather and competitiveness of crop. The weeds dry weight and their count were significantly higher in those treatments, in which the tree was allowing to grow normally with irrespective of soil barrier or irrigation as per requirement of crop. In this case natural growth of tree creates hindrance in cultural operation and equipment used for cultivation can not approach up to the base of tree. In this way some spaces are left over around the tree without cultural operation which helps in survival of perennial weeds. In case of pure crop the values of weed count and dry weight m^{-2} were almost similar to that intercropped with trees.

5.6.2 Weed density and dry matter accumulation under mustard

In rabi crop, *Chenopodium album*, *Fumaria parvifolia*, *Anagallis arvensis*, *Melilotus alba*, *Melilotus parviflora*, *Vicia sativa*, *Cyperus rotundus* and *Cynodon dactylon* were common weeds occurred in the field. Infestation of weeds during first year was more as compared to second year however the weeds were almost similar in tree-crop system to that pure crop during both the years at 30 days after sowing. Weeds m^{-2} at harvest was higher, where irrigation provided to the crop as per their requirement irrespective of pruning of tree up to 70 per cent plant height and tree allowed to grow normally. Irrigation helps the crop for better yield but simultaneously it also help in better growth and dry matter yield of weeds presence in the field. Besides that in mustard senescence of leave occurred before harvesting of crop at that tree crop allow more light

to floor vegetation. Those weeds (*Chenopodium spp., Anagallis spp., Spergula arvensis, Asphodelus spp.*) came in later stages of crop, they were got benefit of light due to shading of leaves. The similar results were also obtained in case of dry weight of weeds at 30 days after sowing and at harvest.

5.7 Light interception

5.7.1 Light intercepted by an intercrop (blackgram) in tree-crop system

The light infiltered through tree canopy is available to the under storey crops and determines its productivity. The multiple canopy layers in agroforestry system absorb more solar radiation and use it efficiently to produce higher biomass. The advantages of higher absorption of solar radiation in intercropping system can be successfully extended to agroforestry system. In agroforestry system total biomass production may be higher than pure cropping but the productivity of crops always depends upon the quantum of light available to crop in tree-crop system.

Light interception at 0.5, 1.0, 2.0, 3.0 and 4.0 m away from the tree base were varied significantly in tree allow to growing normally and pruning of tree up to 70 per cent plant height. Light intercepted by crop under tree-crop system at 0.5 m away from tree base was 21.15 to 23.56 per cent less in pruning of tree up to 70 per cent plant height and 37.52 to 42.60 per cent less in tree allow to grow normally as compared to pure crop. It indicated that 70 per cent pruning had transmitted more light as compared to tree allowed to grow normally. The similar observation also observed by Thakur and Singh (2002) in case of *Morus alba*, in which 75 per cent canopy removal allowed more light transmission as compared to 0, 25 and 50 per cent canopy removal. In another study, light intensity was minimum in *A. auriculiformis* under without pruning, but the intensity under went a sharp rise on pruning (Datta and Dhiman, 2001). Although several studies have already been proved that the light interception in tree-crop system is less as compared to open field (Hazra and Patil, 1986; Thakur and Singh, 2002; Behari *et al.*, 1994; Basawaraju and Gururaja Rao, 2000). The light interception in crop was gradually increased with increasing distances from tree base in both the treatments. In tree-crop system the effect of tree on light interception was more visible at 0.5 m away from tree

base after two years of plantation as compared to 1.0, 2.0, 3.0 and 4.0 m away from tree base.

5.7.2 Light intercepted by an intercrop (mustard) in tree-crop system

The results and trend were similar to kharif crop. However the quantum of light intercepted by the crop during rabi season may be different. The light interception in crop was 7.10 to 42.25 and 6.02 to 36.69 per cent under pruning of tree up to 70 per cent plant height and tree allow to growing normally respectively at 0.5 m away from tree base. These values were significantly less as compared to light intercepted by the crop at 1.0, 2.0, 3.0 and 4.0 m away from tree base. The light interception was 4 per cent higher in pruning of tree up to 70 per cent plant height as compared to tree allowed to grow normally at 0.5 m away from tree base. In general, the light interception increased gradually with increasing distances from tree base. Overall the effect of tree on light availability to intercrop was seen up to first and second row in both the treatments (pruning of tree up to 70 per cent plant height and tree allowed to grow normally). In tree-crop system, light intercepted by the crop was less as compared to pure crop at 15, 30, 60, 90 DAS and at harvest respectively.

5.8 Effect on micro-climate in tree-crop system

5.8.1 Kharif season

5.8.1.1 Temperature

Below tree canopy temperature under tree allowed to grow normally at different dates after sowing was less as compared to pruning of trees up to 70 per cent plant height. It means in pruning the light transmission was comparatively higher, which induced higher temperature as compared to tree allowed to grow normally. In tree-crop system temperature was 4.86 and 8.81 per cent less below tree canopy as compared to open field at different dates after sowing. The microclimatic conditions to be more favourable below canopy of trees (Huxley, 1983; Corlett *et al.*, 1989; Hazra and Patil, 1986; Ramkrishna *et al.*, 1981). A similar finding was also reported in case of *Acacia nilotica*, the temperature

was 1 to 2^0 C was less below the canopy as compared to open canopy (Viswananth *et al.*, 1998).

5.8.1.2 Humidity

Humidity under tree canopy was 25.81 to 30.55 per cent and 18.42 to 21.43 per cent higher in tree allowed to grow normally and pruning of tree up to 70 per cent plant height respectively than open field irrespective of different dates after sowing. A positive interaction, which is often attributed to agroforestry, is the amelioration of micro-climate (temperature, humidity and wind speed). The microclimatic effect due to shelterbelt plantation are well documented but in case of agrisilviculture or silvipasture system, higher relative humidity below tree canopy has been observed by Hazra and Patil ,1986; Ramkrishna and Sastri,1977.

5.8.2 Rabi season

5.8.2.1 Temperature

Changing pattern in temperature due to tree in rabi season was almost similar to kharif. However the temperature in case of tree allowed to grow normally was 2.01 to 6.61 per cent less at different dates after sowing compared to open field during first year and these values were higher (7.73 to 16.95 per cent) during second year. Similarly in case of pruning of tree up to 70 per cent height, the temperature under tree canopy was 0.31 to 2.51 per cent less compared to open field at different dates after sowing.

5.8.2.2 Humidity

The humidity under tree canopy in both the treatments (tree allowed to grow normally and pruning of tree up to 70 per cent plant height) was higher than open field at different dates after sowing during both the years. Under tree canopy, the light does not reach directly and some part of light is only transmitted by the canopy, which lowers the temperature as well as the evaporation.

5.9 Shade length of tree (*Albizia procera*)

5.9.1 Kharif season

Shade length is varying with time and months. Shade length and their area increased with increasing height and canopy of tree after a year of plantation, shade length was up to 2.76 meter from tree base and after two year it had gone up to 3.17 meter from tree base.

5.9.2 Rabi season

In rabi season, the shade of tree had gone up to 1.56 meter after a year of plantation and after two year the shade length was reached up to 2.90 meter from tree base. Observations in kharif and rabi indicated that shade length differ with different month of the year.

5.10 Soil moisture

Moisture content in soil at 0.5 m and 1.0 m was slightly less as compared to 2.0 m and 3.0 m away from tree base at 0-15 cm soil depth. Similar results were also found in case of 15-30 cm soil depth during both the years. A similar finding was also reported elsewhere in different studies (Malik and Sharma, 1990; Sanjay Kumar *et al.*, 2001; Pant and Singh, 1998; Bhaskar *et. al.*, 1991). Among different treatments, the moisture content was less in those treatments in which crop received one irrigation at flowering as compared to crop received irrigation as per their requirement. In another condition, where tree and crop was separated by soil barrier, the moisture content at 0.5, 1.0, 2.0 and 3.0 m away from tree base was almost similar under 0-15 and 15-30 cm soil depth because the soil barrier did not allow the root to inter in crop area, which helped in minimizing the competition for moisture and nutrients.

5.11 Root length density and specific root length

Knowledge of the root distribution of trees is essential to understand the ecological niche of a tree species to design agroforestry system and its management to optimize the productivity of trees and crops in various agroforestry systems (Huxley, 1983; Von

Maydell, 1987; Toky *et al.*, 1989). Root length density (cm root length / cm^3 soil volume) and specific root length (m root length / g dry weight of root) after one and two years planting showed that soil barrier was fully able to restrict the movement of root. But in case of other treatments (trees allow to growing normally and pruning of tree up to 70 per cent plant height) the horizontal movement of roots after a year of planting was observed up to 1.0 m. Although the root length density was higher 0.5 m away from tree base and it decreased with subsequent increase in distances from tree base. Similarly, specific root length was less at 0.5 m away from tree base and it increased with increasing distances from tree base. Similar observations were also made by Ram Newaj *et al.*, 2000; Ram Newaj *et al.*, 2001; Toky *et al.*, 1989. Many other workers (Toky and Bist, 1992; Dhyani *et al.*, 1990, Odhiambo *et al.*, 1999) had also reported that in general, the root density declines with vertical depth and distance from tree. The root length density and specific root length were less in pruning of trees up to 70 per cent plant height as compared to tree allowed to grow normally.

5.12 Pruned biomass

After a year of planting the pruned biomass (leave and twigs) of tree was 0.43 to 1.19 kg $tree^{-1}$ and it was two to three fold more after two years of plantation.

5.13 Changes in physico-chemical properties of soil

Changes in pH, electrical conductivity and organic carbon were very much nominal after two years as compared to initial value. However, the pH, electrical conductivity and organic carbon were higher at 0-15 cm soil depth as compared to 15-30 cm soil depth under different treatments. The values of these parameters at different distances from tree base were also similar to each other. After two years of experimentation, no definite trend was observed due to treatments at different distances from tree base under 0-15 and 15-30 cm soil depths. Similar results were also found in case of available nitrogen, phosphorus and potassium. The content of nitrogen, phosphorus and potassium in soil was less at 15-30 cm depth as compared to 0-15 cm depth.

Summary and Conclusion

CHAPTER VI

SUMMARY AND CONCLUSION

A field experiment entitled "Studies on tree-crop interaction in *Albizia procera* based agroforestry system in relation to soil moisture, light and nutrients" was conducted at National Research Centre for Agroforestry, Jhansi (U.P.) during two consecutive years (2000-01 and 2001-02). The experiment comprising six treatments viz. T1- Planting of tree allow to grow normally + crop, T2 - Pruning of tree up to 70 % plant height + crop, T3 - Tree allow to grow normally + soil barrier + crop, T4 - Pruning of tree up to 70 % plant height + soil barrier + crop, T5 - T1 + irrigation as per requirement of crop, T6 - Pruning of tree up to 70 % plant height + irrigation as treatment 5 and pure tree and pure crop (control). The experiment was conducted in randomized block design with three replications. Blackgram – mustard crop sequence was included as intercrop in tree-crop system. The research findings during field observations are summarized as here under:

During first year, the growth performance of *Albizia procera* (height, collar diameter and crown diameter) was less with intercrops (blackgram-mustard) as compared to that pure tree, but after well establishment of tree, the growth of trees was improved with intercrops during second year compare to that pure tree.

During kharif, germination of crop (blackgram) in first row from the tree base was less as compared to second, third and fourth rows from tree base during both the years. The higher germination of crop was observed in pruning of tree up to 70 per cent plant height irrespective of irrigation and soil barrier as compared to other treatments during both the years. Overall, the germination of crop in pure crop was higher as compared to tree-crop system irrespective of treatments and different rows the tree base.

The similar effect was also noticed in case of plant height and branching of crop. The effect of tree was observed only up to second row on these parameters. However, this effect was more pronounced during second year. The pruning of tree up to 70 per cent plant height associated with irrigation or soil barrier having significant effect on plant height of the crop in which crop growth was better than other treatments.

The effect of trees on yield attributes of blackgram was only observed in first row of crop from tree base in which number of pods was 4.06 to 9.44 per cent less as compared to second row of crop from tree base during first year and this difference was widen during second year. Among all the treatments, pruning of tree up to 70 per cent plant height significantly had higher values of yield attributes either with irrigation or soil barrier. On the basis of two years study of tree-crop system it may be concluded that the contribution and/or importance of above ground growth resources (light) on growth and yield was more than below ground growth resources (moisture and nutrients). In other way management practices like pruning, soil barrier and irrigation may help to increase the availability of these growth resources. On the basis of the yield achieved under different treatments, the effect of light, moisture and nutrients were quantified which indicated that the reduction in yield due to light was 3.68 to 4.50 per cent, due to irrigation (when the rain was terminated before pod formation on blackgram) was 10.82 and due to nutrients was 1.75 to 2.0 per cent. In overall comparison, the grain yield of crop in pure system was 6.58 to 20.71 per cent higher under various treatments as compared to that tree-crop system.

In case of rabi crop (mustard) germination was not affected due to tree during first year but second year the germination was less in first and second row as compared to third and fourth row from tree base. During first year tree did not exert any adverse effect on germination, plant height and branching of crop but during second year, tree had competed with crop and the competition was observed only up to first row from tree base. It indicates that the competitive effect of tree was begun after well establishing of trees. Similar effect was also observed in case of yield attributes.

Among different treatments, pruning of tree up to 70 per cent plant height had significantly affected growth and yields attributes irrespective of irrigation and soil barrier.

As per importance of growth resources, it is concluded that during initial year when tree has less competition with crop, the moisture availability may be contributed more than other resources. In this way required amount of irrigation had increased

mustard yield 18.53 to 16.16 per cent than crop received only one irrigation. Similarly, pruning induced more availability of light to the intercrop and it contributed about 6.77 per cent grain yield than tree allowed growing normally. The yield reduction due to nutrients at this stage was less than 2 per cent.

The dry weight of weeds and their count were significantly higher in those treatments, in which the tree was allowed to grow normally irrespective of soil barrier or irrigation as per requirement of crop. In case of pure crop the values of weed count and dry weight were almost similar to intercrop. Similar results were also obtained in rabi crop. However the weed species are different during rabi season.

During kharif crop (blackgram), the light intercepted by under storey crop was more in pruning of tree up to 70 per cent plant height than tree allowed to grow normally. However the value of light intercepted by crop was 21.15 to 23.56 per cent and 37.52 to 42.60 per cent less in pruning up to 70 per cent plant height and tree allowed growing normally respectively. Similar effect was also noticed in rabi crop (mustard) but value of light interception may be varied in kharif crop.

In kharif season (blackgram) temperature was 4.86 and 8.81 per cent less below tree canopy in tree-crop system as compared to open field. Similarly, humidity under tree canopy was 18.42 to 30.55 per cent higher than open field. Changing pattern in temperature and humidity due to tree in rabi season was almost similar to kharif season.

Moisture content in soil at 0.5 m and 1.0 m was slightly less as compared to 2.0 m and 3.0 m away from tree base at 0-15 cm soil depth during rabi season. Similar results were also found in case of 15-30 cm soil depth during both the years. Among different treatments, the moisture content was less in those treatments in which crop received one irrigation at flowering as compared to crop received irrigation as per their requirement. In another condition, where tree and crop was separated by soil barrier, the moisture content at 0.5, 1.0, 2.0 and 3.0 m away from tree base was almost similar under 0-15 and 15-30 cm soil depth.

Root length density and specific root length after one and two years of planting showed that soil barrier was fully able to restrict the movement of root. But in case of other treatments (tree allowed to growing normally and pruning of tree up to 70 per cent plant height) the horizontal movement of roots after a year of planting was observed up to 1.0 m.

Changes in pH, electrical conductivity, organic carbon, available nitrogen, phosphorus and potassium were very much nominal after two years as compared to initial value. However, the pH, electrical conductivity, organic carbon, available nitrogen, phosphorus and potassium were higher at 0-15 cm soil depth as compared to 15-30 cm soil depth under different treatments.

Photograph

Plate 1. A view of experimental details

late 2. A view of intercrop (blackgram) with *Albizia procera* under 70% pruning in front and in back side naturally growing tree

Plate 3. A view of naturally growing tree before sowing of rabi crop

Plate 4. Soil barrier around the tree for minimizing competition for soil moisture and nutrients in between tree and crop

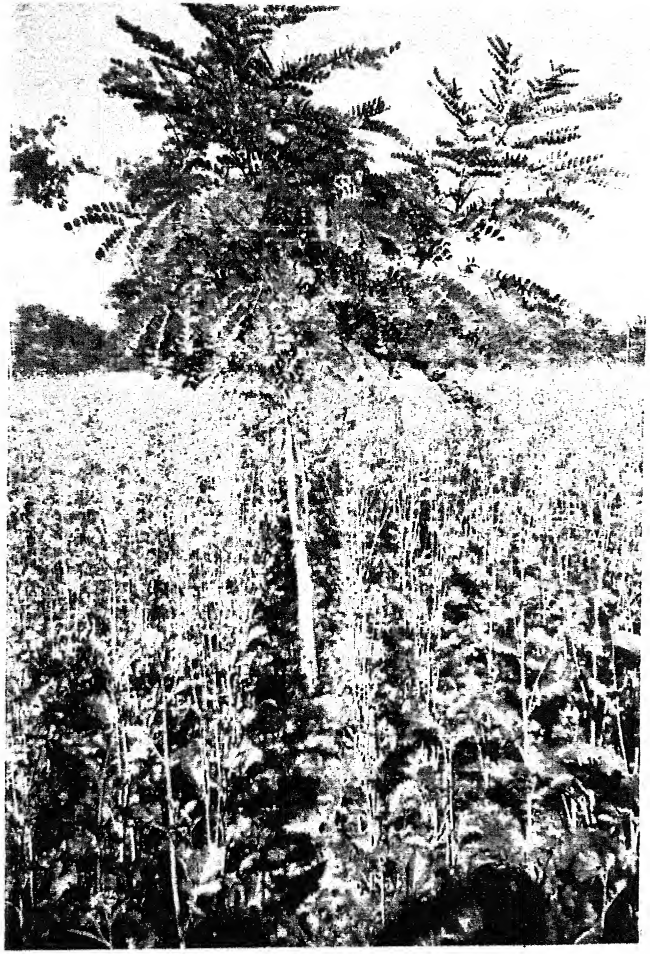


Plate 5. Growth of intercrop (mustard) under pruned condition of tree without soil barrier

Plate 6. Growth of intercrop (mustard) under pruned condition of tree with soil barrier

Plate 7. A view of intercrop with tree at flowering stage of crop

Plate 8. A view of intercrop with tree at maturity stage of crop

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Appendices

APPENDIX I

Meteorological conditions during the experimental period (June, 2000 to October, 2002)

Month	Temperature ^{0}C		Relative humidity (%)		Rainfall (mm)	Evaporation (mm day $^{-1}$)
	Maximum	Minimum	I	II		
June, 2000	36.4	26.1	79	53	193.1	5.6
July	32.6	25.0	89	68	348.1	3.3
August	33.0	25.0	91	67	90.8	3.5
September	34.1	22.3	90	51	29.1	4.3
October	35.5	16.0	86	26	0.0	4.5
November	30.2	10.3	91	31	0.0	3.2
December	26.0	5.3	94	38	0.0	2.4
January, 01	21.9	4.2	94	49	0.2	2.3
February	28.0	7.6	89	38	0.0	4.3
March	33.8	12.1	82	24	0.5	6.0
April	38.7	18.9	68	31	18.6	9.4
May	41.0	25.6	66	33	34.4	11.2
June	35.7	25.3	83	57	377.7	6.9
July	31.2	24.8	94	75	407.8	3.0
August	33.2	24.4	93	66	289.9	3.2
September	36.4	22.4	85	43	28.2	4.5
October	34.0	18.1	87	36	17.4	4.0
November	28.7	10.2	91	29	0.0	2.8
December	24.7	6.7	95	33	0.0	4.1
January, 02	22.6	5.6	94	45	0.0	1.9
February	25.6	9.3	95	46	40.4	2.5
March	33.5	13.1	83	29	0.0	5.2
April	38.5	17.5	68	24	0.0	7.6
May	43.4	26.3	49	19	5.8	12.2
June	41.9	26.7	56	26	41.2	10.9
July	38.4	27.8	68	41	40.4	9.7
August	36.9	26.9	81	52	339.2	7.9
September	31.1	23.9	94	78	116.5	3.6
October, 2002	34.4	20.0	88	46	0.0	4.0

APPENDIX II

Analysis of variance growth parameter of *Albizia procera*

Characters	Mean sum of squares			
	2001		2002	
	Treatments	Error	Treatments	Error
Height (m)	0.076	0.095	0.133	0.112
Collar diameter (cm)	0.501	1.031	0.794	0.956
Crown diameter (m)	0.236	0.071	0.296	0.186

APPENDIX III

Analysis of variance growth and yield attributes of blackgram

Characters	Mean sum of squares			
	2001		2002	
	Treatments	Error	Treatments	Error
Germinated plants running m^{-1}				
1st row from the tree base	7.889	1.997	11.489	1.281
2nd row	12.456	1.531	19.400	2.092
3rd row	13.033	1.625	11.989	2.622
4th row	8.622	1.139	18.092	7.183
Plant height (cm)				
1st row from the tree base	30.378	7.724	49.181	36.959
2nd row	28.089	6.047	19.703	21.778
3rd row	11.178	10.010	27.434	30.670
4th row	86.556	12.458	11.405	13.313
Branches $plant^{-1}$				
1st row from the tree base	2.122	0.314	2.574	1.692
2nd row	2.222	0.589	2.197	1.378
3rd row	1.867	0.433	1.594	1.422
4th row	2.558	0.475	2.829	0.564
Pods $plant^{-1}$				
1st row from the tree base	106.756	3.614	62.142	12.996
2nd row	118.358	6.325	66.605	26.309
3rd row	133.114	8.381	130.811	56.252
4th row	154.856	15.364	163.622	19.560
Seeds pod^{-1}				
1st row from the tree base	0.042	0.099	0.170	0.207
2nd row	0.091	0.047	0.298	0.162
3rd row	0.135	0.055	0.245	0.207
4th row	0.271	0.048	0.238	0.129
Grain yield (g) running $meter^{-1}$				
1st row from the tree base	7.092	3.692	144.803	11.891
2nd row	11.347	6.347	189.231	76.768
3rd row	12.581	4.264	183.232	36.994
4th row	20.800	8.292	133.670	16.913
Test weight (g)				
1st row from the tree base	3.656	0.889	1.071	2.710
2nd row	3.656	1.756	3.309	5.762
3rd row	1.556	1.322	7.280	4.315
4th row	1.867	0.533	12.589	4.413
Grain yield q ha^{-1}	0.258	1.692	4.02	6.52

APPENDIX IV

Analysis of variance growth and yield attributes of mustard

Characters	Mean sum of squares			
	2000-01		2001-02	
	Treatments	Error	Treatments	Error
Germinated plants running m^{-1}				
1st row from the tree base	3.167	1.133	0.733	0.425
2nd row	1.958	2.825	0.681	0.889
3rd row	0.922	3.006	2.067	0.592
4th row	4.967	1.333	0.558	0.158
Plant height (cm)				
1st row from the tree base	152.525	334.417	102.59	104.18
2nd row	400.356	212.781	134.689	160.389
3rd row	243.392	235.408	219.733	155.125
4th row	677.333	389.575	169.733	287.950
Branches $plant^{-1}$				
1st row from the tree base	2.258	8.725	13.21	5.60
2nd row	20.556	22.197	17.458	9.875
3rd row	39.242	16.024	39.033	12.575
4th row	7.914	8.297	69.300	11.567
Siliquae $plant^{-1}$				
1st row from the tree base	22670.59	25454.06	9333.670	595.197
2nd row	20044.86	17046.20	10974.752	410.078
3rd row	29152.36	11908.31	9275.014	576.522
4th row	15073.61	13868.49	14871.325	1535.291
Seeds $siliqua^{-1}$				
1st row from the tree base	5.68	2.09	1.62	2.25
2nd row	0.96	1.87	1.764	1.077
3rd row	2.91	1.33	1.926	1.273
4th row	1.09	1.19	2.979	1.061
Grain yield (g) running $meter^{-1}$				
1st row from the tree base	488.52	559.20	225.64	11.00
2nd row	629.94	191.59	224.60	5.90
3rd row	382.06	234.57	194.203	12.809
4th row	34.87	111.04	167.810	12.694
Test weight (g)				
1st row from the tree base	0.33	0.27	0.10	0.10
2nd row	0.61	0.37	0.121	0.073
3rd row	0.43	0.34	0.142	0.066
4th row	0.63	0.48	0.266	0.125
Grain yield q ha^{-1}	2.62	0.82	15.90	4.59

APPENDIX V

Analysis of variance weed density and dry matter accumulation under blackgram

Characters	Mean sum of squares			
	2001		2002	
	Treatments	Error	Treatments	Error
Weed count m^{-2} at 30 DAS	1.447	0.438	3.326	0.197
Weeds dry weight (g m^{-2}) at 30 DAS	1.064	0.176	1.273	0.055
Weed count m^{-2} at harvest	1.835	0.293	1.231	0.384
Weeds dry weight (g m^{-2}) at harvest	0.740	0.098	0.489	0.332